INFLUENCE OF DIFFERENT TYPES OF SOIL ON THE WATER QUALITY IN CULTURE PONDS

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Dedicated to my beloved parents

CERTIFICATE

This is to certify that this Dissertation is a bonafide record of the work done by Shri.Akshaya Panigrahi, under my supervision and that no part thereof has been presented before for any other degree.

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PREFACE

Aquaculture, being more remunerative than agriculture, is developing into a prime industry tapping the enormous turnover of bioenergy for the benefit of mankind. Aquaculture interacts with the environment. Though it depends on self-renewable natural resources, sustainable development needs conservation and management of these resources. Thus, environmental friendly aquaculture practices may be prioritized in developmental plans and research. Such sustainable development which elucidates conservation and management of soil and water and in turn aquatic plant and animal genetic resources, should be ecologically non-degrading, technically appropriate, economically viable and socially acceptable.

In veiw of these factors, understanding the ecological aspect of the culture systems is imperative. Pond soil plays several important and dynamic roles in the food chain and production cycle viz. as a source of various organic and mineral compounds which enter into water after biochemical and chemical changes,in oxygen balance of water, pH regulation and in sulphur, phosphorus, nitrogen and carbon cycles. The quality of pond water is highly influenced by the nature of bottom soil.

A perusal of literature reveals that several studies on the influence of types of soil on water quality in the inshore water, lake, backwater, ricefields, etc. are available. Although results of such studies are invaluable in understanding the process of exchange between soil and water, it is realized that condition in culture ponds are far more complex because of the diversity of culture practices, high densities of fish/prawn stocks maintained, different feeding patterns and the significant raising of trophic levels through the intensive use of feed and fertilizers.

Among all the marine products, shrimps account for a giant share because of their universal appeal, excellent taste, persistant demand and high unit value. The world market for shrimps has expanded rapidly in the recent past touching nearly US $ 6,500 million. In India prawns form a prominent export commodity and account for 57% by quantity and 70% by value in the total marine product export. However, the wide variation in prawn yield from pond to pond makes it necessary to examine the chemical and biological quality of soil and water (Rajyalakshmi et al. 1988). Similarly brackishwater milk fish/mullet culture also faces potential ecological problems related to acid sulphate soils and deterioration of water quality (Poernomo and Singh, 1982) which needs urgent attention.

Now, when coastal aquaculture is poised for an explosive growth with a promising future, an indepth understanding of soil water interaction in brackishwater culture ponds is not only important to augment the yield by expansion and/or intensification but also important in assessing the magnitude of negative ecological feed back effects like siltation, turbidity, build up of organic rich sediments, hypoxic or anoxic bottom water, toxic outgassing, spread of diseases etc.

The present study attempts to elucidate behaviour of phosphorus, nitrate nitrogen, carbon, sulphur, anions and cations on different types of soil, (alluvium, acid saline, hydromorphic saline) subjected to different salinities in different seasons and their influence/introduction on/with water quality, nutrients and productivity. Thus, understanding the inherent fertility status of soil and its influence on water quality, an efficient fertilization scheme for successful aquaculture can be developed for these brackishwater environments.

This dissertation consists of **INTRODUCTION, MATERIAL AND METHODS, RESULTS, DISCUSSION, SUMMARY AND BIBLIOGRAPHY** which covers the scope, objective, method, outcome and interpretation of the study undertaken.

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INTRODUCTION

The interaction of Soil and water in culture ponds is a subject of unusual scientific and ecological interest. It's scientific interest springs from its application in aquaculture, limnology, pollution control and geochemistry. It's ecological importance needs no emphasis, since 72% earth's surface is covered by submerged soil or sediments (Aiyer & Rajendran, 1987). Pond soil is an integral part of every pond and interacts in every metabolic process. For this reason investigation of the pond environment ought to include the bottom sediment as well as the water and should continue throughout the season. Soils play an important role in the production of fish/prawn from pond; in supplying nutrients to the inflowing water, in the mineralization of organic bottom deposits, and in the storage and release of nutrients to the water (Matida, 1967).

Aquaculture has emerged as a major frontier of fish production in the developing countries both for domestic consumption and export. Currently about 65,000 ha of brackish-water area is under aquaculture in India, of which over 52,000 ha are under traditional farming practices in West Bengal, Kerala, Karnataka and Goa (Alagarswami, 1991). While relatively more comprehensive data are available on water quality of culture ponds in India, there has been practically very little study of the soils of brackishwater culture ponds. With the increasing demand for prawns in international market, prawn culture in brackishwater ponds has gained a great momentum. In the recent years brackishwater aquaculture can be identified with the production of a single commodity, the prawns due to it's expanding export market, high unit value and short term cropping pattern. Most rational proposition to achieve better yield for years to come is to intensify the prawn farming in low lying brackishwater areas in the light of locally available technologies in which soil and water plays important role. Again disasters from several types of diseases of prawns and fishes can be averted through good management (Alagarswami, 1991).

Sediments are regarded as the store house of the essential elements/molecules of productivity in overlying water and even the pollutants. Most important raw materials for production in aquatic system are organic and inorganic form of carbon, nitrogen & phosphorus, light and micronutrients. Benthic algae, which constitute the major food organisms for fishes and prawns in brackishwater culture ponds, derive their nutrients either directly from the soil or from soil-water interface and accordingly the productivity of such ponds depends largely on the nature and properties of bottom soils (Mandal, 1962).

The importance of physicochemical characteristics and their individual or synergistic effect on survival, growth and production of fish/prawn are well known (Verghese et al., 1982). To keep the aquatic habitat favourable for existance, physical and chemical factors like temperature, salinity, turbidity, pH, Eh, alkalinity, hardness, cations, anions, organic carbon, photosynthetic pigments and dissolved gases like oxygen, carbon dioxide and reducing gases like hydrogen sulphide & methane working lethal on fish life, will exercise their influence individually or synergistically, while the nutrient status of soil and water play an important role in governing the production of plankton organisms and in turn on primary production in culture ponds.

Kerala is a state with notable physical features of backwater areas adjoining the sea. In different parts of these tract, large areas of pyritic peaty or marshy soils occur. In Kerala, the total brackishwater areas including the lower reaches of rivers, the brackishwater lakes and adjacent low lying fields, mangrove swamps is estimated at about 2,43,000 hectares. About 50% of the toal water logged areas could be utilized for prawn farming (Anon, 1978). At present only about 5,117 ha of low lying fields are being utilized for traditional prawn farming (Rao, 1980). Out of the different types of soil in Kerala such as red loams, laterite and brown hydromorphic association, coastal alluvium, riverine alluvium, greyish onttukara, hydromorphic saline, acid saline, black soils and forest loam etc. the brackishwater/coastal areas are mainly of coastal alluvium, riverine alluvium, hydromorphic saline and acid saline soil types (Fig. 1).

The areas of pyritic peaty or marshy soils are known as 'Kari' soil, because of its intensive black colour. Soils of these areas have high organic deposit. The whole area lies

1-2.5 meter below mean sea level. These soils are submerged for major part of the year and are periodically inundated by saline water of tidal inflow. These soils are with characteristic jarosite $(KFe_3)(SO_4)_2(OH)_6$ within a depth of 50 cm from surface. It is a characteristic feature of acid sulphate soils. Money and Sukumaran (1973) reported that acidic soils of Kerala recorded pH 5 or below under moist condition and still less on drying. The productivity of brackishwater ponds of these areas are reported to remain poor for several years. The fish production is badly affected by low pH, unfavourable ionic composition of the pond water, the frequent presence of finely dispersed ferric hydroxide scum, and poor supply of algal feed.

The water quality management is critical to aquaculture production. The water quality of fish pond in India was studied by Sewell (1927), and he reported the mortality of fish in Museum tank in Calcutta. Since then a number of workers have studied the physico-chemical condition of inland waters either in connection with fish mortality or on general hydrological survey. To mention a few of them, there are studies by Alikunhi et al.(1948) Ganapati et al. (1945, 1950, 1953), Chacko and Srinivasan (1954), Thivy et al. (1948), Mookerjee and Bhattacharya (1949). Besides these stray observations, a more systemic and extensive study of the physico-chemical quality of fishery water was taken up by Madras Fisheries Department in connection with Madras Rural Pisciculture scheme (Menon et al. 1959).

The physical, chemical and biological properties of submerged soil differs markedly from that of uplands. The major immediate change that occur in the soil environment due to submergence is depletion of oxygen (Aiyer & Rajendran, 1987). As stated by various authors, under submergence due to depleted oxygen supply the surface soil profile differentiates in two distinct layers, an oxidised or aerobic layer near soil surface at the soil water interface and the reduced or anaerobic layer below the soil surface where free oxygen is not available (Poernomo & Singh, 1982; Rajyalakshmi,1980).

The evidence for the presence of a relatively high concentration of oxygen in the aerobic layer was reported by Pearsall (1939) and Mortimer (1941) on lake muds and sediments and swamp soils. They characterised this layer by the presence of typical oxidised radicals such as ferric iron, nitrate and sulphate while the mud below was low in oxygen and contained ferrous iron, nitrate, ammonia and sulphide. Mortimer (1941), Hickling (1962) have explained the reason for diurnal and seasonal fluctuations of dissolved oxygen of bottom water and its role in production. Nutrient ions are produced by decomposition of precipitated organic matter.

Effect of submergence on the acidity of a soil was reported, as pH of soils kept at different moisture contents was changed. Money and Sukumaran (1973) reported that the acid saline water-logged soils are highly acidic and sometimes free sulphuric acid is formed by the oxidation of sulphur compound present in the food - fossils found under soil. Ohle (1938) found that by raising pH, nutrients such as phosphate adsorbed on ferric hydroxide were easily washed out.

The role of different forms of carbon, nitrogen, phosphorus as well as the organic matter in aquatic productivity has been investigated by many workers (Aston and Hewitt, 1977; Roman and Tennore, 1978; Shankaranarayanan et al, 1979). The soil profits more as it is constantly enriched in organic matter, phosphate and carbonate (Stangenberg, 1943). The main process taking place in the bottom of the pond, are accumulation and decomposition of organic matter. As a result of the accumulation of organic matter important macro-elements are eliminated from the pond water and immobilized at the bottom, while the decomposition of organic matter not only releases mineral compound, but contributes also to the dissolution of unavailable phosphate and carbonate. Environmental factors controlling the input of organic matter to sediments, fall into four general catagories, viz. biological, physical, chemical and geological (Sucevic & Dujmov, 1988).

Each of the elements carbon, nitrogen, phosphorus and sulphur are directly or indirectly connected with the decomposition of organic matter. Again modification of organic matter in the surface sediments is to a large degree dependent on microorganisms and metazoan biomass. The solids falling to the culture bed are enriched in carbon, nitrogen and phosphorus relative to the natural sediments (Holmer, 1991), possibly causing physico-chemical changes in sediments below or adjacent to fish farm operations, including increase in sediment organic carbon content, followed by increased sediment oxygen consumption rates and decrease in redox potential (Brown&Gretzedk, 1987), generation of hydrogen sulphide and methane (Lumb, 1989) and increase in inorganic and organic nitrogen (Kasper et al. 1988), phosphorus, silicon, calcium, copper and zinc (Rosenthal et al. 1988).

Phosphorus is often considered as one of the most critical factor in the maintenance of biogeochemical cycles in fish ponds and is vitally important in the operation of energy transfer systems. Hickling (1971) made a very categorial statement that "It is unlikely that a case exists where phosphates would not be beneficial.". It is available and not the total phosphorus which is important to aquatic productivity owing to the fact that phosphate ions in the bottom soils form insoluble compound, with iron and aluminium under acidic conditions, and with calcium ions under alkaline conditions (Banerjea and Mandal, 1965). Higher amount of available phosphorus in brackishwater pond soils has been reported by Chattopadhyay (1978) and may be considered favourable for brackishwater fish culture not only due to the fact that phosphorus is one of the essential nutrient element for pond productivity and which often occur in very meagre amount in nature, but also due to its importance in growth and multiplication of blue green algae which form the major fish food organism in brackishwater ponds.

Sediments acts as reservoir of phosphorus in natural system. According to Hays and Phillips (1958), the dynamic interaction between water and sediment may be represented as

$$\text{P in aqueous phase} \rightleftharpoons \text{P in solid phase}$$

(a small fraction of the whole) (a large fraction of the whole)

In acid soils phosphate ions are precipitated as ferric phosphate (Einsele, 1938), but Mortimer (1954) & Hickling (1971) prefer to regard the precipitation process as one of adsorption of phosphate ions on colloidal ferric hydroxide because the concentration of phosphate decreases well below the concentration calculated from the solubility of ferric phosphate. Hepher (1958) indicated that, most of the added phosphate is fixed in the pond mud as calcium phosphate.

Nitrogen is very essential, found either in elemental form or in combination with other forms in the ecosystem. Nitrogen cycle occuring in a body of water between elemental nitrogen and organic nitrogen constitute N_2 fixation, ammonification, nitrification and denitrification. Pillay et al. (1962) observed prodctivity of brackishwater ponds to depend largely on the amount of available nitrogen in bottom soils and hence the low values of it emphasize the use of higher amount of nitrogen in brackishwater ponds in terms of organic and inorganic fertilizations. Kawaguchi (1950) observed escape of nitrate ions with water exchange because nitrate is not well absorbed by soil compared with ammonia. In addition, nitrate is reduced to nitrogen by chemical and biological process at the boundary of reducing and oxidizing layers. Nitrate dynamics in soil and water is being investigated by many workers like Venkateswarlu (1969), Mollah et al. (1979), Stefenson and Richards (1963) and Mortimer (1941).

Hardness, alkalinity and salinity are certain measures to define important properties of water and bottom soil. Hardness is total concentration of calcium ions expressed as $CaCO_3$. Alkalinity is capacity of water/soil to accept protons due to carbonate, bicarbonate and hydroxide ions. Water soluble anions like chloride, sulphate, bicarbonate and carbonate are important to influence soil condition and thus water quality. Gopalswamy and Raychowdhuri (1970) reported chloride followed by sulphate to be the most dominant anions for coastal saline marshy soils of West Bengal. Koyama and Sugawara (1951) found that sulphate ions in water is taken in to soil by coprecipitation. Water soluble cations like magnesium, calcium, sodium and potassium play important role in soil & water interaction. The exchange of potassium between soil and water is relatively less dependent on carbon turnover cycle. Lyzimetric investigation of ponds (Wrobel, 1967) proved that calcium is the most washed out factor in culture ponds.

Available sulphur is quantitatively the most important electron acceptor for oxidation of organic matter. The accumulation of sulphide and in particular pyrite is quite common in marine and estuarine deposits all over the world (Moorman, 1963). The reduction of sulphur leads to the formation of H_2S which in toxic concentration destroys most forms of biota.

The nutrients determine the potential fertility of water masses (Harvey, 1960) and therefore it is important to study the distribution and characteristics in different geographical location and seasons. The synthesis of organic compounds from inorganic constituent of water is termed as primary production which is effected almost entirely by the photosynthetic activity of plants, with trace of organic matter formed by chemosynthesis. Concentration of chlorophyll is a useful and simple tool for estimating phytoplankton standing crop and is now more frequently used than the cell number and cell volume methods. The important contributions in this regard are of Dehadri and Bhargava (1972), Bhargava (1973), Nittal and Rao (1989). Tides in Cochin backwater are of mixed semi diurnal type with maximum range of about one meter as reported by (Qasim and Gopinathan, 1969). Hydrographic feature and water quality of this area is also investigated by Saraladevi et al. (1983); Qasim and Madhupratap (1981).

Water quality is environment related and inputs such as liming for sanitation and correction of hydrogen ion concentration, fertilization, stocking and feeding interacts with the pond environment. At least fourteen essential elements that plants and organisms obtain from the soil, out of which, calcium and magnesium are applied as lime in regions where they are deficient. Although not rated as fertilizer, lime, does exert a profound nutritive effect. Three fertilizer elements other than micronutrients are nitrogen phosphorus and potassium. As in agriculture, in aquaculture too, chemical fertilizers have been found to play an important role in increasing production (Hickling, 1962; Lin, 1986). Further workers from various countries have categorically emphasised the need for applying nitrogenous phosphatic fertilizers in place of non-nitrogenous phosphatic fertilizers for achieving higher fish production in ponds (Swingle, 1947; Sunderson & Iyer 1987; Zhadin, 1958; Wrobel, 1962; Wolny, 1966).

Few studies have been conducted to develop pond fertilization techniques for brackishwater, but several studies have shown that yields of fish/shrimp could be increased by fertilizer application (Johnson, 1954; Fortes et al. 1986). There have been a tremendous amount of research on fertilization techniques for freshwater ponds (Mortimer, 1954; Boyd, 1990). Most brackishwater pond fertilization has been based on modification of freshwater pond fertilization procedures.

Smith (1984) concluded that nitrogen is more important as a limiting nutrient in ocean water than in freshwater and nitrogen fertilization is often considered more important in brackishwater ponds than freshwater ponds.

It is common practice to apply nitrogen fertilizers on brackishwater ponds to increase the N:P ratio (Association of south east Asian Nations, 1978; Boyd and Daniels, 1992). Low concentrations of silicon limit diatom growth (Kilham, 1986;

Schelske *et al*. 1986) and silicion fertilization might increase the proportion of diatoms in phytoplankton communities of brackishwater ponds.

It has been suggested that fertilization of brackishwater pond by inorganic and organic fertilizers helps in the growth of biotic communities and subsequent high production of prawn (Rajyalakshmi, 1980; Mandal, 1980; Chattopadhyay and Mandal, 1980).

The present investigation comprises a field study and a lab. study. Attempts are made to study the interaction between soil and water and to define the fertility status of these culture ponds. In the lab. experiments, the objective is to know the relative response of nitrogenous and phosphate fertilizers in three types of soil differing in their reaction.

MATERIALS AND METHODS

THE STUDY AREA

Out of the nine types of soils in Kerala, the coastal brackishwater areas are mainly of riverine alluvium, coastal alluvium, acid saline and hydromorphic saline types. The soil map of Kerala (NARP,1990) is given in Fig. 1.

Four centres were selected each with number of stations in different localities in the coastal Kerala districts of Ernakulam, Alleppey and Kottayam. In each station a group of minimum three to maximum six ponds were selected for the study. Empahsis had been given to make the centres as diverse as possibles. Similarly stations within every centre were distributed over the whole area. In each station ponds were randomly selected depending upon the availability of culture ponds with existing culture practices. In the presesnt study total thirty seven ponds were selected for investigation.

Centre I: Vyttila being situated in the centre of Pokkali region with high fluctuation of salinity was found ideal for this study. Soil type is of hydromorphic saline type. Due to high content in sulphur, this is also referred as acid sulphate type.

Fig.1: SOIL MAP OF KERALA

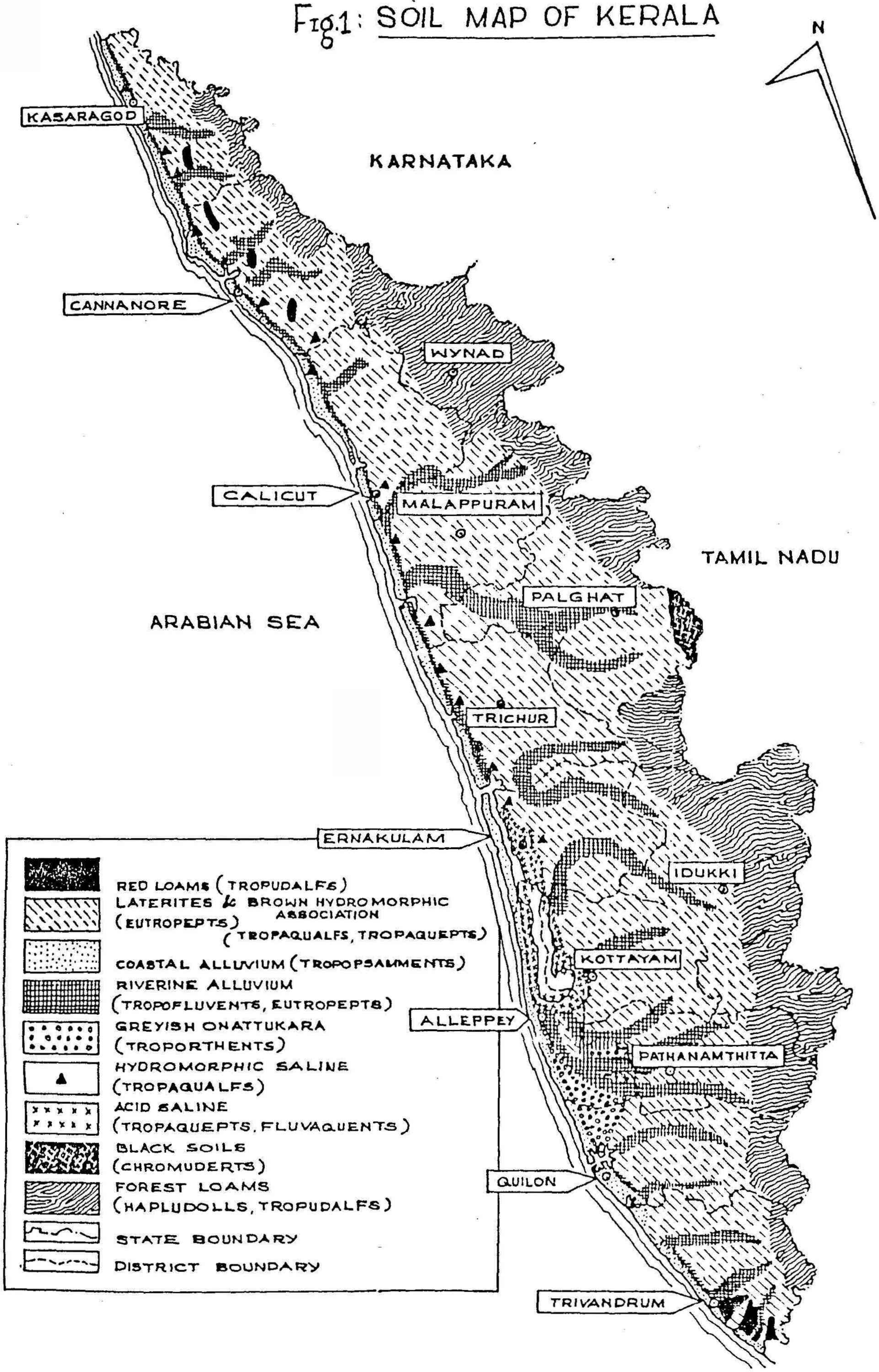
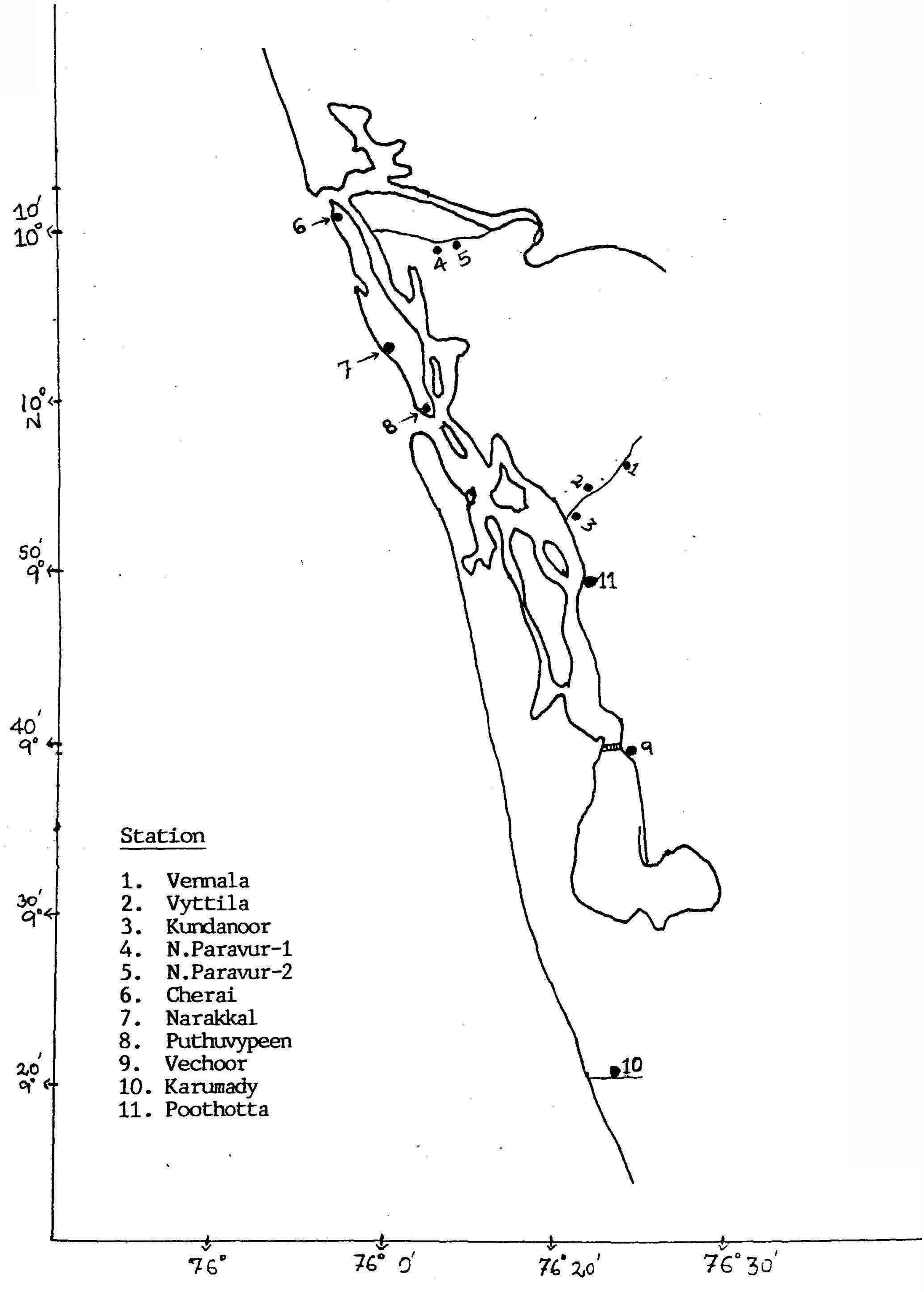


Fig: 2 Map showing the location of stations.



In this centre three stations were selected as per the distance from sea.

Station-1: Vennala: This is situated upstream on the bank of river chitrapuzha. Here three ponds (Pond No.1, 2, 3) were selected with area respectively 0.48 ha, 0.86 ha and 0.46 ha. Traditional prawn culture is practised in these perennial ponds.

Station-2: Vyttila: Here six ponds (Pond No.4, 5, 6, 7, 8, 9) were selected with 0.15, 0.15, 0.15, 0.36. 0.4 and 0.5 ha respectively. In these ponds fishes like Chanos chanos, Mugil cephalus, Etroplus suratensis and Indian major carps are cultured during low saline phase (June-January) of the year and during high saline phase, prawns Penaeus indicus and Penaeus monodon are stocked. Natural water exchange through sluice gates is practised. Fertilization and liming is done to maintain the productivity of ponds.

Station-3: Kundanoor: It is located downstream on the river bank of Chitrapuzha. Three ponds (Pond No. 10, 11, 12) with area 0.16, 0.08 and 0.07 ha were selected in this station.

Centre-II : Riverine alluvium soil occures mostly along the bank of rivers and their tributaries. They are very deep soils with surface texture ranging from sandy loam to clay loam. They are moderately supplied with organic matter, nitrogen and potassium (NARP,1990). For this type of soil along the bank of river

Periyar situated near North Paravur were selected.

Two stations were selected viz. station 4 and 5 each having three ponds. Station 4 has three ponds viz. pond No.13, 14, 15 with area of 8.5 ha, 5 ha and 2 ha respectively. Station 5 has three ponds viz. Pond No. 16, 17, 18 with area of 1.1 ha, 2 ha, 1.5 ha were selected.

Centre-III: Coastal alluvium soils extend all along the coast of Kerala with few discontinuity overlapping of other types of soils. These soils show incipient development. The texture is dominated by sand fraction with very rapid permeability. The horizon is usually thin and the surface texture is observed to be loamy sand and sandy loam. they are of low fertility level and also low in organic matter, and cation exchange capacity (NARP, 1990). In this centre area selected along the coast of Vypeen island with three stations viz. Cherai, Narakkal and Puthuvypeen.

Station-6: Cherai: Three perennial culture ponds (pond No. 19, 20 ,21) were selected with area respectively 0.5, 0.45, 0.65 ha. In these ponds prawn culture is practised in part of the year with proper stocking, feeding and water exchange.

Station-7: Narakkal: Three ponds viz. Pond No.22, 23, 24 with area 0.05, 0.05, 0.78 ha respectively are selected.

Station-8: Puthuvypeen: Here culture of brackishwater fin

PLATE I: Photograph showing a typical culture Pond

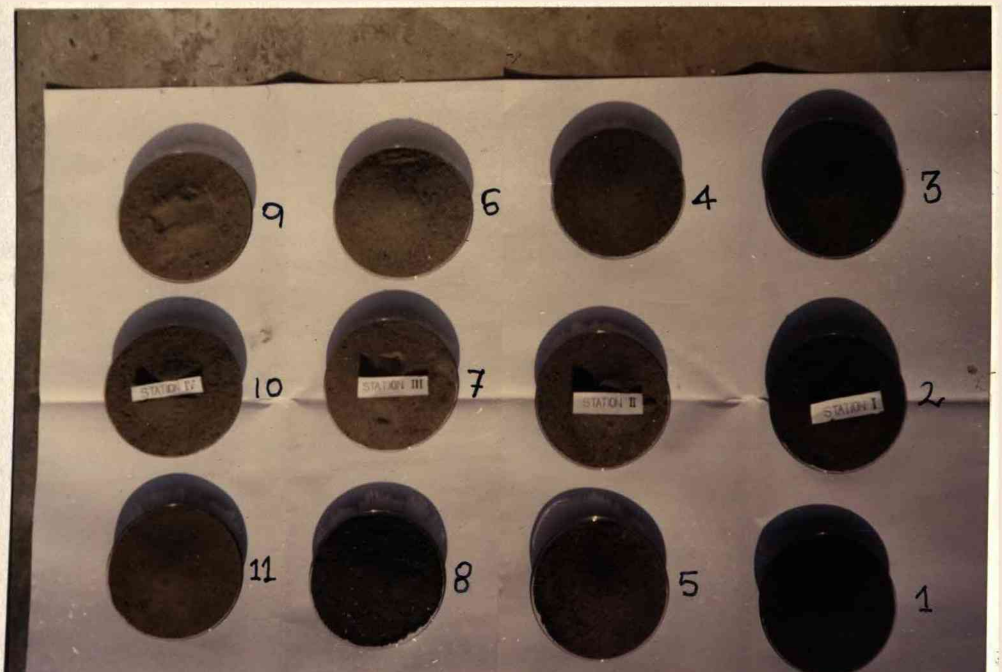


PLATE II: Colour characteristics of soil samples from different stations fishes such as Mugil cephalus, Etroplus suratensis, Chanos chanos and Lates calcarifer are practised; prawns like Penaeus monodon and Penaeus indicus are also being cultured in these ponds. In this station four ponds viz. pond no. 25, 26, 27, 28 with area 0.2, 0.18, 0.22, 0.21 ha were selected.

Centre-IV: This centre is having acid saline type of soil and is distributed in Alleppey and Kottayam districts.

They are acidic in reactions and tend to be saline because of ingress of sea water.

Station-9: Vechoor: Situated in the vicinity of Thanneermukkom. Three ponds with area of 0.65, 0.48 and 0.25 ha are selected.

Sttion-10: Karumady: It is situated in Ambalapuzha taluk, Alleppey district. Three ponds (No.32, 33, 34) of area 0.41, 0.32 and 0.04 ha respectively were selected.

Station-11: It is located at Poothotta in Ernakulam district. Pond Nos. 35, 36, 37 with area 0.15, 0.10 and 0.14 ha were selected.

In addition to this field study, a laboratory experiment was conducted to understand the response of fertilizers in brackishwater environment.

Laboratory experiment:

The response of three common fertilizers viz. urea, ammonium sulphate and superphosphate on three types of soil ranging from acid, neutral and alkaline reaction as reflected in physico-chemial nature of soil and water in primary productivity has been studied. The study was made in the laboratory in rectangular perspex tank of 200 litre capacity. The soil collected for this purpose are hydromorphic saline soil, acidic in reaction with dry pH of 4.5-5.5. Liming is done with slaked lime $(Ca(OH)_2$ to increase the pH from acidic to neutral and alkaline. Lime requirement for a definite pH increase is calculated from both potential acidity and exchange acidity of soils as reported by Pillai & Boyd (1984).

Soil is spread upto 7.5 cm depth, above which a water column of 30 cm is made to stand.

Treatment: Urea and ammonium sulphate are two nitrogenous fertilizers whereas superphosphate is phosphate fertilizers. Urea, superphosphate and ammonium sulphate are applied at the rate of 250 kg/ha individually to each of the soil types. This dose is maintained uniform to avoid any kind of biasing between quantity of fertilizers used. Control for each tank is maintained without fertilization.

Sample of water and soil is collected from these tanks once before application of fertilizers and subsequently after each six days interval till 36th day. Thirty sixth day is selected becauses of high decline in the productivity of water as reflected by the decayed blooms. Salinity of water is maintained at 15 ppt by mixing sea water and fresh water.

Fertilizer	Chemical form	Source	Composition
Urea	$CO(NH_2)_2$	Synthetic	42-45% nitrogen
Ammoniumsulphate	$(NH_4)_2SO_4$	"	21% nitrogen
Superphosphate	$Ca(H_2PO_4)_2$	"	16% W.S.P.A.

The soil samples were analysed for pH, alkalinity, TEC, CEC, available phosphorus, nitrate-nitrogen & organic carbon and the water sample were analysed for pH, salinity and nutrients. Along with these parameters trend in gross production, pigments and cell counts are also observed at every six days interval.

METHODS

Analysis of sediment is a means of quantifying the resultant of an essentially dynamic process from a sample taken at a moment of time. The nature of a sediment is determined by the complex interaction of a large number of factors.

COLLECTION OF SAMPLE

Soil: The quantity of the sample required and the means of obtaining it must depend largely on the nature of analysis contemplated. In the present study soil samples were collected in duplicate from different ponds, put into separate polythene bags and labelled internally and externally. The method of collection in shallow ponds was by means of a soil sampler which conists of a metal cylinder to be pressed into surface soil and a column of 10 cm soil from soil water interface can be trapped. However, in very deep ponds Vanveen grab was used.

To make the samples representative a number of samples were collected from different places in a pond and mixed to have a final sample. The number of samples varied from three to ten depending on the size of the pond.

Water: Water samples were collected from subsurface, about 15-20 cm below the surface level of pond water. As far as possible care was taken to make the samples representative by collecting from different places and mixing it to have the final sample. Water samples were stored in 500 ml capacity clean plastic bottles. Before drawing, the sample bottles were washed with ambient water. The water samples were preserved in an ice box till they were analysed in the lab.

SAMPLING FREQUENCY

Regular monthly sampling was done from all these stations during newmoon and fullmoon days preferably. The time of sampling was from 08:00 hrs to 12:00 hrs.

SEASON

Following the season classification given by Qasim and Gopinathan (1969).

Premonsoon (February - May)

Monsoon (June - September)

Postmonsoon(October - January)

In the present study the data were classified as Premonsoon months (April-May), Monsoon months (June - September) and Post monsoon months (October-November).

SEDIMENT ANALYSIS

Depending upon the existing facilities, the air dried samples were analysed for:-

I - Texture

II - Hydrogen ion concentration (pH)

III - Redox Potential (Eh)

IV - Conductivity (EC)

V - Cation exchange capacity (CEC)

VI - Total exchangeable metallic cation (TEC)

VII - Exchangeable cations K^+, Ca^{++}, Na^+

VIII - Alkalinity, Chloride

IX - Organic Carbon

X - Available sulphur

XI - Available phosphorus

XII - Soil nitrate nitrogen

TEXTURE

Mechanical analysis of soil is done by International pipette method as given by Ganguly (1982), which essentially consist of two distinct operations such as, dispersion and fractionation of sample into various separates.

20 gm of soil sample (dried and seived through 2 mm mesh size) was taken, moisted with water, and added to it 30 ml of 6% H_2O_2 and heated intermittently after subsequent addition of H_2O_2 till evolution of CO_2 ceased. Cooled, diluted with 100 ml water, and 25 ml of 2N HCL added and filtered through No-1 whatman filter paper, washed with hot distilled water several times until free of cations. Soil is transferred to sedimentation cylinder

PLATE III: Photograph showing grain size analysis by International Pipette Method

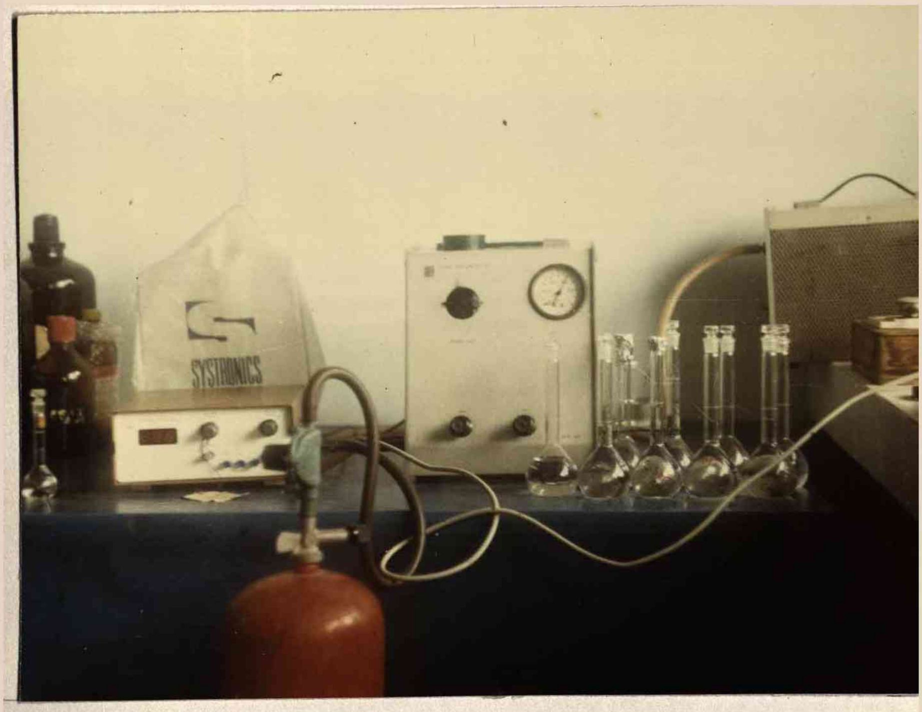


PLATE IV: Flame photometer.

by washing with distilled water. To this 10 ml of IN NaOH was added and filled upto 1000 ml. 10 ml of the suspension is drawn twice, first for silt + clay and next for clay fraction, leaving gap between pipetting depending upon the atmospheric temperature.

$$\% \text{ Silt + Clay} = \frac{\frac{m}{v} \times V\ (100-x)}{w \times 100} \times 100$$

$$\% \text{ Clay} = \frac{\frac{n}{v} \times V\ (100-x)}{w \times 100} \times 100$$

% Sand = 100-(% Clay + % Silt)

where m = wt of silt + Clay

n = wt of clay

v = volume pipetted

V = total volume of suspension

w = wt of the soil taken (gm)

x = % of moisture

SOIL pH

The pH of wet and dry (1:2.5) soil samples were estimated by using an "ECL Digital pH meter 5652". For dry pH estimation, 10 gm of dry soil sample was mixed with 25 ml distilled water and shaken for 30 minutes.

SOIL Eh

Eh is calculated by using a TOSHNIWAL-Digital pH meter in the soil suspension of 1:2.5 dilution.

SOIL EC

Electrical conductivity was measured in a conductivity bridge for different soil samples throughout the period of study. A correction factor was used for correctiong the conductivity values at 25^{o}C and expressedas mmhos/cm.

CATION EXCHANGE CAPACITY (CEC)

CEC was determined by "Modified Perkin's method" as described by Iswaran (1980).

To 1 gm of soil sample 25 ml of 1N $MgCl_2$ was added, shaken for 5 min, filtered through whatman No-42, washed with water till chloride was removed. The soil is transferred from filter paper to conical flask to which 0.4 % EDTA (25 ml) is added and filtered again. To the filtrate 100 ml distilled water and 10 ml buffer solution (NH_4Cl and NH_4OH in 1:5 ratio) of pH 10 is added, followed by six drops of Eriochrome black-T indicator and titrated against 0.1 N $MgSO_4$ with end point from blue to wine-red.

$$\underset{\text{(me/100 gm)}}{\text{CEC}} = \frac{\text{ml of } MgSO_4 \text{ x Normality of } MgSO_4 \text{ x } 100}{\text{wt. of soil}}$$

TOTAL EXCHANGEABLE METALLIC CATIONS (TEC)

TEC was determined by shaking 2.5 gm of soil with 25 ml of 1N glacial acetic acid for 1 hour and subtracting the pH of 1N glacial acetic acid from that of the mixture (Firman, 1964).

TEC (me/100 gm soil) = 22 (pH of mixture - pH of G.A.A.)

EXCHANGEABLE CATIONS (Soil, K^+, Na^+, Ca^{++})

5 gm of soil was extracted with 25 ml of 1N ammonium acetate solution and available/exchangeable potassium, sodium and calcium were determined with the help of digital "flame photometer model CL-22 D" using the respective filters. The method followed was as given by Ganguly (1982).

Available $K^+/Na^+/Ca^{++}$ (ppm) = ppm from Curve x Total dilution

$$\text{Exchangeable } K^+ \text{(me/100 gm)} = \frac{x \times 25 \times 100 \times 10^3}{10^6 \times 39}$$

$$\text{Exchangeable } Na^+ \text{ (me/100gm)} = \frac{x \times 25 \times 100 \times 10^3}{10^6 \times 23}$$

$$\text{Exchangeable } Ca^{++} \text{ (me/100gm)} = \frac{x \times 25 \times 100 \times 10^3}{10^6 \times 40}$$

SOIL ALKALINITY & CHLORIDE

Routine parameters like alkalinity and Chloride (salinity) content were estimated from filtrate of the soil suspension (1:10 W/V) through Whatman No - 44. Procedure being same as that of water described later. Results reported as

$$Y \text{ mg gm}^{-1} = \frac{x}{10} \times \frac{V}{S(100-M)}$$

Where Y = parameter in question

X = value of Y in mg/l

V = total volume of mud suspension (ml)

S = Weight of fresh mud in suspension (gm)

M = Moisture content of fresh sediment (%)

SOIL ORGANIC CARBON

It is determined by wet oxidation method (Walkly and Black, 1935) with modification as given by Jackson (1968). The procedure is as follows:

A carefully weighed amount (0.5 gm) of smaple (powdered and seived through 0.2 mm seive) was placed in a 500 ml conical flask. To this exactly 10 ml of 1 N potassium dichromate was added. To this 20 ml of concentrated sulphuric acid was added and mixed by gently rotating the flask. The mixture was allowed to react for 20-30 minutes. The sample was diluted with 200 ml distilled water and to this 10 ml of concentrated phosphoric acid was added. The sample was back titrated with 0.5 N Ferrous ammonium sulphate solution using 1 ml of diphenylamine indicator. The end point was the appearance of brilliant green colour from an intial turbid blue colour. The percentage of organic carbon content was calculated using the equation:-

$$\text{Organic Carbon (\%)} = \frac{(S-T)}{2} \times 0.003 \times \frac{100}{\text{wt. of the sample}}$$

Where S = ml. of Ferrous ammonium sulphate used for blan

T = ml. of Ferrous ammonium sulphate for sample titration.

AVAILABLE SULPHUR

This was determined by the method described by Ganguly (1982).

To 5 gm of soil, 25 ml of extracting solution (39 gm of NH_4OAC in 1 litre of Acetic acid) was added, shaken for 30 minutes. A pinch of activated charcoal was added followed by 3 min shaking. After filtering through whatman No. - 42, 5 ml of filtrate was taken to which 1 ml of acid seed solution (6N Hcl containing 20 ppm of S as K_2SO_4) and 0.5 gm of $BaCl_2$ was added and volume was made upto 50 ml. The extinction was measured at 420 nM and compared with that of standard graph prepared from known concentration of K_2SO_4.

$$\text{Available sulphur (ppm)} = \text{Conc. from std. curve} \times \frac{50}{5} \times \frac{\text{Extracting Solution}}{\text{wt. of soil}}$$

AVAILABLE PHOSPHORUS

Available phosphorus in soil was determined following the Olsen's method (1958) as given by Jackson (1968).

Five gm of sample (powdered and seived through 2 mm) was taken in a conical flask to which was added 1 spoon of Darco G-60 followed by 100 ml of $NaHCO_3$ (0.5 mol). After shaking for half an hour, the mixture was filtered through whatman filter paper

No. - 40. From the colourless filterate 5 ml is pipetted out to a 50 ml volumetric flask to which 5 ml of molybdate and 1 ml of diluted stannous chloride was added and volume was made upto 50 ml with distilled water. The extinction is measured at 820 nm and compared with that of standard curve prepared by using known concentration of KH_2PO_4. Available phosphorus is expressed in µg/gm.

$$\text{Available phosphorus } (\mu g/gm) = \text{Con. from std. curve} \times \frac{50}{5} \times \frac{\text{Extracting Solution}}{\text{st. of soil}}$$

SOIL-NITRATE NITROGEN

The method followed was as given by Adoni (1985).

To 50 gm of soil, 250 ml of nitrate extraction solution (20 ml 1N $CuSO_4$ + 100 ml 0.6% $AgSO_4$ in 1 litre) and 0.4 gm $Ca(OH)_2$ and 1 gm $MgCO_3$ were added with subsequent shaking and filtered through whatman No - 50. Discarding 1st 20 ml filtrate 25 ml was evaporated to dryness on a hot water bath. The residue was rubbed thoroughly with 0.5 ml phenoldisulphonic acid reagent to dissolve all solids. After diluting with 5 ml of distilled water, concentrated NH_4OH is added till yellow colour developed. The extinction was found out at 410 nM against distilled water blank.

$$\text{Nitrate nitrogen } (\mu g/gm) = \frac{n \times v}{S}$$

Where n = Value of NO_3-N in filtrate (mg/l)
v = Volume of total soil extract (ml)
S = Wt. of dry soil.

WATER ANALYSIS

I - Salinity

II - Dissolved oxygen

III - Total hardness

IV - Total alkalinity

V - Nutrients

VI - Chlorophyll and carotenoids

VII - Primary production

VIII- Cell counts

SALINITY

Salinity was determined by classical Mohr titration method (Strickland and Parson, 1968). For this 10 ml of water sample titrated against silver nitrate solution with Potassium chromate as an indicator. Salinity was calculated by the following formulae

$$S\ \% = \frac{V_1 S}{V_2}$$

Where V_1 = Volume of $AgNO_3$ for titrating 10 ml of sample.

V_2 = Volume of $AgNO_3$ for titrating 10 ml of standard sea water.

S = Salinity of sea water.

DISSOLVED OXYGEN

Water samples were collected using a standard 60 ml "corning" bottle with glass stopper for the estimation of dissolved oxygen.

Traditional 'Winkler's' method with modification (Anon, 1975) was followed.

$$\text{Dissolved Oxygen (ml/l)} = \frac{\text{Titrate Value of Sample} \times \text{Normality of thiosulphate} \times 1.01 \times 8}{100 \times 1.429}$$

TOTAL HARDNESS

Total hardness of water is estimated by following method of Adoni (1985). To 50 ml of sample taken in a flask, 1 ml of ammonia buffer (114 ml of conc. NH_4OH + 13.5 gm of NH_4Cl in 200 ml) was added followed by 5 drops of Eriochrome black T indicator. The colour of the sample turns red which is titrated with EDTA (0.01 N) till clear blue colour appeared.

$$\text{Total hardness (mg/l as } CaCO_3) = \frac{\text{ml of titrant (EDTA)}}{\text{ml of sample}} \times 100$$

TOTAL ALKALINITY

To a 100 ml of sample about 4-5 drops of phenophthalin is added. The pink colour developed, if at all, can be removed by titration with standard sulphuric acid (0.02N) till colour less. Again, 4-8 drops of methyl orange indicator solution was added and titrated till the colour of the solution changed from yellow to faint orange.

$$\text{Phenophthalin alkalinity (mg/l as } CaCO_3) = \frac{P \times N \times 50{,}000}{S}$$

$$\text{Total alkalinity (mg/l as } CaCO_3) = \frac{T \times N \times 50{,}000}{S}$$

Where P = volume in ml of titrant needed to remove pink colour

T = volume of ml of titrant needed (in total)

N = Normality of sulphuric acid

S = Volume of sample (ml)

NUTRIENTS

Water sample for nutrient was collected in a 250 ml narrow mouthed plastic bottle and kept in ice box till analysis. Using visible spectrophotometer (TOSHNIWAL) with a wave length range of 340 - 950 nM, intensities were measured.

Nitrate-Nitrogen: Nitrate-nitrogen was estimated by the method of Morris & Riley's as described by Strickland and Parsons (1968) with modification. To 50 ml of sample 2 ml of buffer reagent (Phenol Solution + Sodium hydroxide solution) was added and with rapid mixing 1 ml of reducing agent (Copper sulphate + hydrazine sulphate) was also added. The flask was kept in dark for 20 hours and latter this sample was mixed with 2 ml of acetone. After two minutes interval, 1 ml each of Sulphanilamide solution and NNED were added and mixed thoroughly. After 10 minutes the absorption was measured at a wave length of 543 nM in the spectrophotometer. Standard nitrate stock solution was prepared and the values were plotted on a graph sheet. Concentration of nitrate was read from the graph and expressed in µg at. NO_3-N/l.

Nitrite-Nitrogen: Nitrite-Nitrogen was estimated by the method of Moris and Riley, as described by Strickland and Parson (1968).

50 ml of water sample was mixed with 1 ml of sulphanilamide solution. After 2 minutes, but not latter than 8 minutes, 1 ml of NNED was added and mixed thoroughly. The extinction was measured at 543 nM. Standard graph was prepared by using standard nitrite solution and nitrite concentration was expressed as µg at. NO_2-N/1.

Reactive phosphorus: The method given by Murphy and Riley, as described by Strickland and Parsons (1968) was followed for determination of reactive phosphorus.

To a 100 ml of sample 10 $\pm$ 0.5 ml of mixed reagent (Molybdic acid, ascorbic acid and trivalent antimony) was added and mixed. The resulting complex heteropoly acid was reduced *in situ* to a blue solution. After 5 minutes, preferably within 2-3 hours, the extinction of the solution was measured at 885 nM. For standard phosphorus, different known concentrations of potassium dihydrogen phosphate was made and the graph was plotted. Phosphate is expressed in µg at. PO_4-P/1.

Silicate-Silicon: Dissolved silicon of the sample was estimated by using the method of Mullin and Riley (1955). To a sample of 25 ml, 10 ml of molybdate solution (prepared by dissolving 4.0 gm of ammonium molybdate in 300 ml of distilled water and 12 ml of concentrated hydrochloric acid (12 N) was added. After 10 minutes, 15 ml of reducing agent (consisted of metol + oxalic acid + sulphuric acid) was added to the sample. The solution was allowed to stand for 2 hours to complete the reduction. Standard graph was prepared by using standard silicate solution and silicate was expressed in µg at. SiO_4-Si/l. Extinction was measured at 810 nM.

CHLOROPHYLL AND CAROTENOID DETERMINATION

The method followed by Jeffrey and Humphrey (1975) as described by Parson et al. (1984) was used for chlorophyll and carotenoid estimation. A known volume of sample was poured into a millipore filtering equipment containing a membrane filter paper. Sample was filtered under ½ atm. pressure vacuum. To this 3-5 drops of magnesium carbonate solution was added while filtering. Filter was drained thoroughly and was placed in a 15 ml glass vial. To this 10 ml of 90% acetone was added. This was allowed to stand overnight in a dark container in a refrigerator. The contents of each tube was centrifuged for 5-10 minutes at 200 rpm. The supernatent solution was decanted into the spectrophotometer cell and extinction was measured at different wave lengths (750, 664, 647, 630, 510 and 480 nM). Each extinction was corrected for a turbidity blank by subtracting the 750 nM reading from 664, 647 and 630 nM absorptions. The 510 nM and 480 nM absorbance were corrected by subtracting 2x and 3x 750 nM absorbance respectively. The amount of pigment in the original sample was determined using the equation given below.

For chlorophylls

$$\text{Chlorophyll } \underline{a} \text{ (Chl. } \underline{a}) = 11.85\ E_{664} - 1.54\ E_{647} - 0.08\ E_{630}$$

$$\text{Chlorophyll } \underline{b} \text{ (Chl. } \underline{b}) = 21.03\ E_{647} - 5.43\ E_{667} - 2.66\ E_{630}$$

$$\text{Chlorophyll } \underline{c} \text{ (Chl. } \underline{c}) = 24.52\ E_{630} - 1.67\ E_{664} - 7.60\ E_{647}$$

For plant carotenoids

$$\text{Plant carotenoids (Cp)} = 7.6\ E_{480} - 1.49\ E_{510}$$

Where E stands for absorbance at different wave lengths obtained above and Chl. a, Chl. b, Chl. c, and Cp are the amount of chlorophyll a, b, c and carotenoids (µg/ml), if 1 cm light cuvette is used.

$$\text{mg chlorophyll or carotenoid/m}^3 = \frac{c \times v}{V \times 10}$$

Where V = volume of sample in litre,

c = substituted value for Chl. a, Chl. b Chl. c and Cp in the above equation

v = volume of acetone in ml

$$\mu g/l = mg/m^3$$

PRIMARY PRODUCTION

Light and dark bottle oxygen technique (Gaarder and Gran, 1927) was used for the estimation of primary production. In this method, composition samples were collected in 125 ml "Corning" bottle with glass stopper. These bottles were categorised into three groups, viz. initial bottle (IB), light bottle (LB) and dark bottle (DB). The dark bottles were painted black and wrapped in aluminium foil.

Initial dissolved oxygen concentration was determined by fixing the initial bottle with 'Winkler A' and 'Winkler B'. The light and dark bottles were kept in the lab, under fluorescent light for a period of three hours in simulated *in situ* conditions. In dark bottle only respiration take place.

The difference in the oxygen content between light and dark bottle was taken as gross production. Primary production was calculated as follows:

$$\text{Production (mgC)} = \frac{O_2\ (\text{ml/l}) \times 0.536}{\text{PQ}}$$

Where PQ (Photosynthetic quotient) is always 1.25.

0.536 is a constant.

$$\text{Gross Production (mgC/l/hr)} = \frac{O_2\ (\text{ml/l}) \times 0.536}{\text{PQ}\ (1.25) \times T}$$

Where T = No. of hours of incubation

GROWTH ESTIMATION

For the quantitative estimation of the cell, lml of culture were taken after thorough mixing and fixed in Lugol's iodine. These cells were counted with caliberated haemocytometer and represented as cells x 10^4/ml.

DATA PRESENTATION

The data collected were classified into three seasons. The range & mean $\pm$ S.D. of selected parameters for different centres seasonwise are given in Tables. The trend of different parameters stationwise are depicted in Figures. Textural classes of soil are elucidated in triangles.

In the lab. experiments the trend of gross production, cell counts and pigments are shown in Figures. Correlation matrix between selected parameters are given in Tables.

Statistical analysis

The relation between different physico-chemical parameters were statistically analysed by correlation matrix using the pooled data of different ponds in differet seasons. Two way ANOVA worked out to find the significance of variation between centres and between seasons for the selected parameters. For analysis of variance six ponds were randomly taken from each centre. By critical difference test, variation at a centre in different seasons and in a season at different centrers was tested. Similarly for the lab. expt. these analyses were carried out to assess the efficiency of fertilizer and to establish correlations between the selected parameters.

R E S U L T S

Morphological feature

The soils of different centres are differing in their characteristic colour, consistency, plasticity and smoothness and texture (heavy/light) which are discussed in the next chapter. The photograph showing the soil samples of differnt stations is given in plate II.

Texture

The soil textural classes are determined by following the classification given by Brady (1980). The ponds were found to have diverse textural classes ranging from sandy to clayey. However, within a station the ponds are more or less similar in their composition of sand, silt and clay. Taking the avereage value of all seasons for the ponds of a particular station the textural classes (Fig. 3) are defined as follows.

Centre	Station	Textural Class
I	1. Vennala	Loamy sand
	2. Vyttila	Sandy clay loam
	3. Kundanoor	Sandy loam
II.	4. N.Paravur 1	Sandy loam
	5. N.Paravur 2	Sandy loam
III.	6. Cherai	Sandy loam
	7. Narakkal	Sandy loam
	8. Puthuvypeen	Clay loam

Table 1
Average soil textural composition in different stations seasonwise

Centre	Station		Premonsoon	Monsoon	Postmonsoon
I	1	Sand (%)	83.64	82.74	79.62
		Silt (%)	7.22	8.85	8.98
		Clay (%)	9.14	8.41	11.40
	2	Sand (%)	66.92	69.84	69.74
		Silt (%)	10.64	11.69	10.71
		Clay (%)	22.44	18.47	19.55
	3	Sand (%)	66.90	71.59	68.37
		Silt (%)	7.78	7.4	8.73
		Clay (%)	25.32	21.00	22.90
II	4	Sand (%)	77.89	74.02	74.00
		Silt (%)	9.48	11.18	10.67
		Clay (%)	12.63	14.80	15.33
	5	Sand (%)	71.38	72.63	69.73
		Silt (%)	9.12	12.84	13.27
		Clay (%)	19.50	14.53	17.00
III	6	Sand (%)	82.36	74.43	74.11
		Silt (%)	6.21	10.52	10.39
		Clay (%)	11.43	15.05	15.50
	7	Sand (%)	75.46	74.80	74.47
		Silt (%)	7.81	10.01	10.70
		Clay (%)	16.73	15.19	15.83
	8	Sand (%)	49.48	47.16	47.50
		Silt (%)	19.76	22.81	21.39
		Clay (%)	30.46	30.03	31.11
IV	9	Sand (%)	67.25	70.95	70.86
		Silt (%)	15.08	11.97	13.07
		Clay (%)	17.67	17.08	16.07
	10	Sand (%)	76.62	77.60	78.90
		Silt (%)	10.25	10.07	10.13
		Clay (%)	13.13	12.33	10.97
	11	Sand (%)	72.84	73.13	73.94
		Silt (%)	11.73	11.30	12.23
		Clay (%)	15.43	15.57	13.80

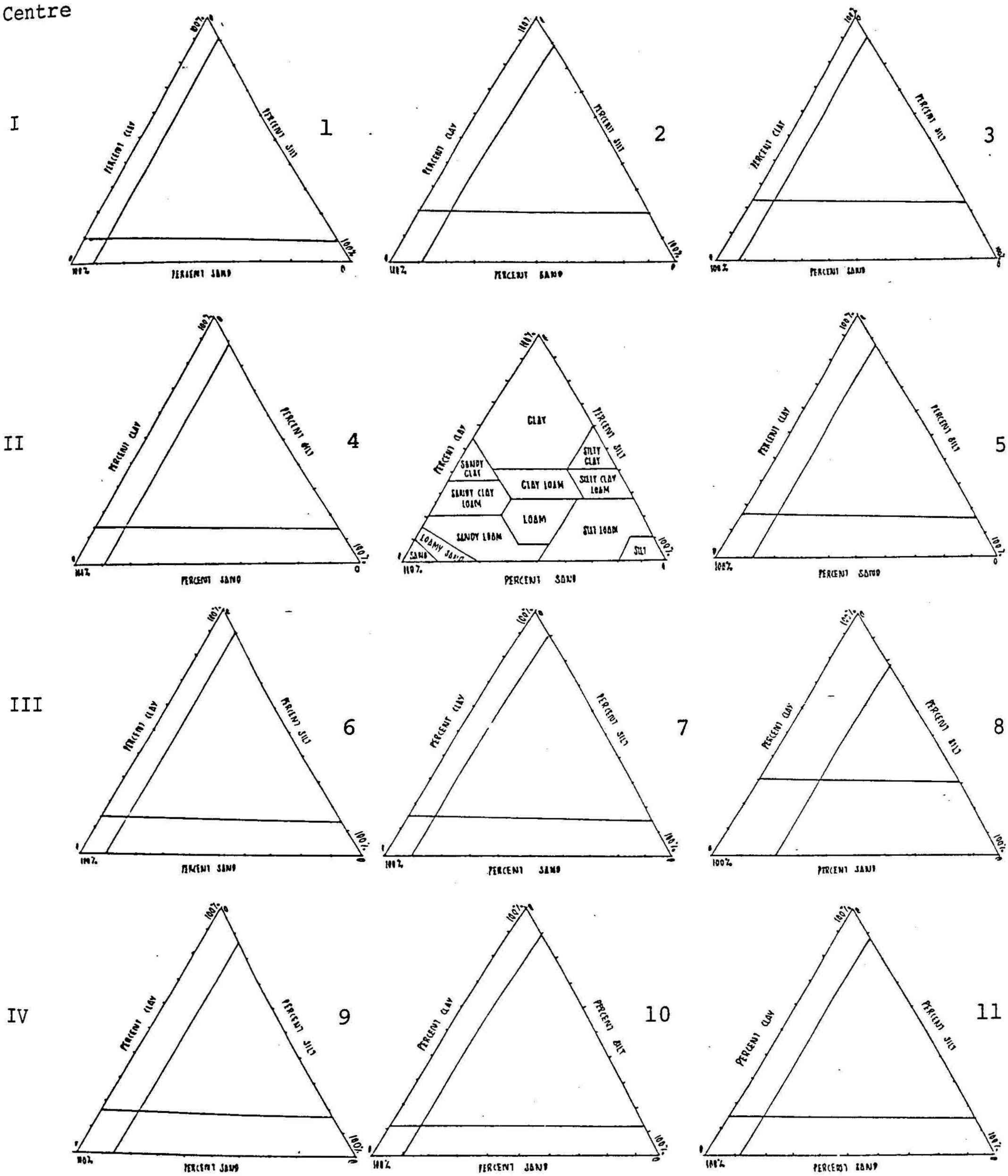


Fig. 3 Soil textural classes in different stations (1-11)

IV.	9.	Vechoor	Sandy loam
	10.	Karumady	Sandy loam
	11.	Poothotta	Sandy loam

Most of the ponds belongs to sandy loam type. Sand percentage range was found to be between 38.19 at Puthuvypeen and 90.28% at Cherai. Ponds at Vyttila station showed relatively low perentage of sand as that of Puthyvypeen station.

Surface area phenomenon is mostly affected by the small size and fine subdivisions of silt and clay. Clay percentage was found to have significant correlation with soil EC (r = 0.569), soil alkalinity (r = 0.296), soil organic carbon (r = 0.306), and with soil available sulphur (r = 0.335) all significant at 1% level. Also with exchangeable cations like K^+, Na^+, Ca^{++} it showed a significant positive correlation r being 0.722, 0.571 and 0.715 all signifcant at 1% level. Percentage of sand was inversely correlated with CEC, TEC and soil phosphate etc.

The percentage composition of sand, silt and clay stationwise and seasonwise is given in Table 3. Monsoon impact was observed, though not very much influential. Except for station 4, 6 and 11 which showed a marginal increase, other stations showed general decrease in clay content during monsoon. Except in station 9, 10 and 11 others showed a general increase in silt percentage in monsoon than that of premonsoon.

Table - 2. The range of selected parameters in different centres.

Table 2a. Centre I

	Premonsoon	Monsoon	Postmonsoon
Water p^H	7.05 - 8.45	7.15 - 7.50	5.45 - 8.18
W. salinity (ppt)	1.40 - 15.41	0.01 - 0.84	0.19 - 3.00
W. Hardness (mg/l as $CaCO_3$)	867 - 2882	27.02 - 101.34	81.47 - 451.8
W.Alkalinity (mg/l as $CaCO_3$)	29-80	16.00-48.00	12.0-65.6
W.phosphate (µg at/l)	7.04-65.2	13.16-53.82	3.0-6.6
W.nitrate (µg at/l)	4.79-42.99	11.2-51.42	3.79-74.3
W.silicate (µg at /l)	20.00-60.5	4.01-80.16	23.20-83.00
Chlorophyll <u>a</u> (mg/m^3)	1.93-74.72	3.61-92.60	4.62-92.30
Chlorophyll <u>b</u> (mg/m^3)	0.27-27.28	15.23-39.3	17.20-50.60
Chlorophyll <u>c</u> (mg/m^3)	2.10-23.84	12.40-46.5	0.48-63.7
Carotenoids (mg/m^3)	2.88-36.08	3.23-25.2	5.20-28.4
Soil p^H	6.95-7.50	5.73-6.90	5.45-6.80
S. Eh (mv)	+376 - +507	+296 - +412	+316 - +426
S. EC (mmho/cm)	3.60-16.60	0.70-8.70	0.90-4.50
S. salinity (ppt)	1.37-16.14	0.46-1.84	0.46-2.92
S. Alkalinity (mg/gm)	0.78-1.68	0.29-2.48	0.59-1.89
S. CEC (me/100 gm)	12-24	17.00-23	10.0-23
S.TEC (me/100 gm)	0.88-9.68	3.74-13.8	2.86-6.16
S.Silt (%)	5.32-18.41	7.00-13.85	8.00-12.30
S.clay (%)	7.98-28.40	8.10-24.8	10.3-25.7
S. organic carbon (%)	0.86-2.55	1.26-3.00	0.63-1.86
S.av.phosphorus (µg/gm)	128-408	40.5-156.8	65.24-107.96
S.nitrate (µg/gm)	3.51-16.05	4.00-14.40	5.60-12.00
Av. sulphur (ppm)	588-4375	912.5-1268	185.8-647
S.exchangeable K^+ (ppm)	152-1024	89-829	125-1335
S.exchangeable Na^+ (ppm)	624-3288	262-2394	320-2500
S.exchangeable Ca^{++} (ppm)	1563-2693	920-1920	1025-1820

Table 2b. Centre II

	Premonsoon	Monsoon	Postmonsoon
Water pH	7.07 - 7.90	7.00 - 7.5	7.14 - 7.56
W.salinity (ppt)	18.6 - 20.10	0.28 - 1.22	3.80 - 6.09
W.Hardness (mg/l as $CaCO_3$)	735 - 2205.88	38.28 - 255.90	570.33-836.00
W.Alkalinity (mg/l as $CaCO_3$)	48 - 68	28 - 48.0	42.40 - 62.8
W.phosphate (μg at./l)	0.7 - 3.04	1.84 - 2.9	0.40 - 0.90
W.nitrate (μg at./l)	1.80 - 5.22	5.60 - 27.63	0.31 - 1.40
W.silicate (μg at./l)	28.2 - 32.40	47.0 - 86.0	27.0 - 56.02
Chlorophyll <u>a</u> (mg/m^3)	10.21 - 29.85	25.4 - 42.50	18.30- 38.48
Chlorophyll <u>b</u> (mg/m^3)	0.70 - 22.4	4.90- 18.90	5.16- 22.6
Chlorophyll <u>c</u> (mg/m^3)	2.91 - 13.44	8.40- 26.0	4.92- 27.2
Carotenoids (mg/m^3)	3.00 - 7.04	3.4 - 18.20	1.48- 20.3
Soil pH	7.50 - 8.25	7.36- 7.81	6.73- 7.34
S. Eh (mv)	+370 - +482	+276 - +428	+228 - 441
S.Ec (mmho/cm)	7.10 - 8.5	1.40- 3.30	1.90- 2.90
S.Salinity (ppt)	4.67 - 14.67	1.48- 1.84	1.61- 1.84
S.Alkalinity (mg/gm)	1.79 - 2.33	1.63- 1.97	0.67- 3.40
S.CEC (me/100 gm)	18 - 24	18 - 22	17 - 19
S.TEC (me/100 gm)	2.86 - 9.24	3.52- 6.16	2.86 - 9-46
S.Silt (%)	5.28 - 12.90	7.32- 15.7	8.30 - 16.40
S.Clay (%)	7.22 - 22.31	8.77- 21.31	11.40- 21.50
S.Organic Carbon (%)	47 - 1.25	0.41- 0.60	0.48- 2.07
S.av. phosphorus (μg at./gm)	26 - 64	4.48- 18.36	20.86- 125.17
S.nitrate (μg at./gm)	3.00 - 8.42	408.0- 808.0	5.00- 7.62
Av.sulphur (ppm)	450.0 - 1563	250 - 962	179.52- 537.90
S.exchangeable K^+ (ppm)	802 - 1064	490 - 856	613 - 890
S.exchangeable Na^+ (ppm)	1828 - 2099	905 - 1303	1280 - 1800
S.exchangeable Ca^{++} (ppm)	1904 - 2605	1031 - 1836	1125 - 1580

Tabe 2c. Centre III

	Premonsoon	Monsoon	Postmonsoon
Water p^H	7.40 - 8.24	7.26 - 7.89	7.18 - 8.78
W.salinity (ppt)	17.80 - 28.50	0.47 - 1.78	5.2 - 16.00
W.Hardness (mg/l as CaCO)	2661 - 4838	27.86 - 292.76	399.7 - 1936
W. Alkalinity (mg/l as $CaCO_3$)	65 - 190	16.0 - 76.0	56 - 198.4
W. Phosphate (µg at./l)	1.56 - 23.4	0.38 - 9.35	0.34 - 4.82
W. Nitrate (µg at./l)	1.509 - 3.59	0.90 - 58.34	1.09 - 4.50
W. Silicate (µg at./l)	26.2 - 58.0	18.4 - 57.2	15.68 - 65.0
Chlorophyll a (mg/m^3)	18.9 - 116.8	25.42 - 60.0	18.39 - 89.4
Chlorophyll b (mg/m^3)	0.6 - 52.30	4.63 - 46.2	2.40 - 27.6
Chlorophyll c (mg/m^3)	6.47 - 41.77	12.20 - 126.6	4.10 - 49.0
Cartotenoids (mg/m^3)	5.40 - 41.4	3.20 - 48.90	1.40 - 32.90
Soil p^H	7.26 - 8.40	6.9 - 8.22	6.92 - 7.56
S. Eh (mv)	+262 - +370	+312 - +380	+287 - +384
S. EC (mmho/cm)	7.10 - 18.00	1.70 - 14.4	2.20 - 11.00
S. Salinity (ppt)	8.40 - 27.67	1.38 - 18.42	1.38 - 31.36
S.Alkalinity (mg/g)	2.40 - 12.2	1.20 - 7.48	0.71 - 17.05
S.CEC (me/100 g)	6 - 25	10.0 - 22.0	10 - 22
S.TEC (me/100g)	1.98 - 25.3	1.98 - 26.2	0.88 - 19.36
S. Silt (%)	0.39 - 23.84	9.2 - 30.8	8.40 - 26.95
S. Clay (%)	9.37 - 35.1	12.98 - 35.0	14.90 - 33.4
S. Organic carbon (%)	0.53 - 2.25	0.19 - 2.46	0.15 - 2.93
S.av.phosphorus (µg at.l/gm)	9.0 - 67.0	4.48 - 112.0	7.20 - 85.6
S. Nitrate (µg at./gm)	9.60 - 23.81	420 - 960	725 - 1300
Av.sulphur (ppm)	600 - 1925	137.5 - 1225	212.93 - 1008
S.exchangeable K^+ (ppm)	220 - 2819	1850 - 1600	160 - 2215
S.exchangeable Na^+ (ppm)	1885 - 4575	1332 - 2225	1405 - 2820
S.exchangeable Ca^{++} (ppm)	1784 - 6870	1094 - 4655	1037 - 4906

Table 2d. Centre IV

	Premonsoon	Monsoon	Postmonsoon
Water pH	7.10 - 7.84	7.23 - 7.73	6.32 - 7.28
W. Salinity(ppt)	3.00 - 4.5	0.08 - 0.47	0.12 - 1.69
W. Hardness (mg/l as $CaCO_3$)	1020 - 2529	27.0 - 135.12	88.89 - 234
W. Alkalinity (mg/l as $CaCO_3$)	34 - 84	20.0 - 58	45 - 100
W. Phosphate (μg at./l)	1.36 - 11.8	0.38 - 21.18	0.30 - 2.08
W. nitrate (μg at./l)	2.62 - 14.2	1.21 - 14.39	1.07 - 3.99
W. Silicate (μg at./l)	25.6 - 59	19.2 - 87.6	12.46 - 66.4
Chlorophyll a (mg/m^3)	15.9 - 37	18.12 - 52.4	5.92 - 21.9
Chlorophyll b (mg/m^3)	4.6 - 19.5	11.3 - 46.8	3.74 - 22.9
Chlorophyll c (mg/m^3)	5.5 - 32.6	5.25 - 75.6	3.46 - 27.8
Carotenoids (mg/m^3)	9.6 - 22.2	14.5 - 44.2	0.18 - 18.6
Soil pH	6.50 - 7.2	5.09 - 7.11	6.27 - 6.78
S. Eh	259 - 409	320 - 458	324 - 500
S. Ec (mmho/cm)	2.70 - 4.2	0.50 - 2.5	0.50 - 2
S. Salinity (ppt)	1.90 - 7.8	0.65 - 1.84	0.7 - 1.47
S. Alkalinity (mg/g)	0.80 - 3.36	0.89 - 3.36	0.42 - 2.10
S. CEC (me/100 g)	19 - 23	18 - 28	19 - 22
S. TEC (me/100 g)	1.98 - 5.72	1.98 - 13.64	1.32 - 5.72
S. Silt (%)	7.90 - 16.67	8.6 - 15.3	8.40 - 17.2
S. Clay (%)	9.75 - 18.3	10.4 - 17.5	9.6 - 16.4
S. Organic carbon (%)	0.95 - 1.93	0.75 - 1.62	0.52 - 1.77
S. Av. Phosphorus (μg at./gm)	11.0 - 25.0	10 - 22.2	7.8 - 18.6
S. Nitrate (μg at./gm)	6.80 - 14.60	4.5 - 9.6	4.5 - 1340
Av. Sulphur (ppm)	125 - 489	130 - 850	112.7 - 1235
S. Exchangeable K^+ (ppm)	79 - 420	55 - 300	59 - 287
S. Exchangeable Na^+ (ppm)	209 - 925	113 - 575	165 - 650
S. Exchangeable Ca^{++} (ppm)	563 - 1520	320 - 910	333 - 920

Parameters	Centre	Premonsoon (April - May)	Monsoon (June - Sept.)	Postmonsoon (Oct. - Nov.)
Water pH	I	7.63 ± 0.40	7.00 ± 0.11	6.62 ± 0.64
	II	7.47 ± 0.26	7.26 ± 0.23	7.39 ± 0.17
	III	7.83 ± 0.35	7.55 ± 0.19	7.97 ± 0.47
	IV	7.35 ± 0.32	7.52 ± 0.18	6.76 ± 0.27
Water salinity (PPt)	I	7.05 ± 4.88	0.38 ± 0.28	1.09 ± 0.96
	II	20.08 ± 2.03	0.90 ± 0.33	4.83 ± 0.88
	III	24.31 ± 4.67	1.038 ± 0.45	10.43 ± 3.97
	IV	3.87 ± 0.55	0.326 ± 0.14	0.58 ± 0.53
Water hardness (mg/l as CaCo2)	I	1376.98 ± 763.34	74.98 ± 24.59	213.36 ± 119.11
	II	1406.91 ± 501.12	146.07 ± 101.40	670.46 ± 116.50
	III	3935.77 ± 916.08	111.90 ± 97.30	1143.99 ± 602.05
	IV	1479.48 ± 544.35	82.09 ± 40.28	138.96 ± 47.77
Water Alkalinity (mg/l as CaCO5)	I	45.08 ± 14.11	31.17 ± 8.67	32.26 ± 16.79
	II	58 ± 8.15	39.5 ± 7.09	56.03 ± 10.75
	III	114.6 ± 59.41	42.1 ± 22.39	129.31 ± 52.37
	IV	62.44 ± 17.54	40.7 ± 15.70	62.40 ± 23.73
Water reactive phosphate phorphorus (µg at/l)	I	33.41 ± 21.97	30.05 ± 14.69	38.16 ± 20.78
	II	1.97 ± 0.89	2.16 ± 0.475	0.61 ± 0.25
	III	8.74 ± 6.72	7.35 ± 9.62	2.17 ± 1.55
	IV	7.63 ± 3.55	6.47 ± 7.39	1.14 ± 0.55
Water nitrate nitrogen (µg at/l)	I	19.15 ± 13.75	29.13 ± 12.74	42.26 ± 22.71
	II	3.02 ± 1.23	19.53 ± 10.56	0.79 ± 0.36
	III	2.25 ± 0.6	24.35 ± 26.67	2.57 ± 1.28
	IV	7.21 ± 4.21	7.47 ± 4.63	2.37 ± 1.01
Water Nitrite Nitrogen (µg at/l)	I	1.965 ± 2.015	1.425 ± 1.51	3.34 ± 2.26
	II	0.517 ± 0.69	0.216 ± 0.137	0.587 ± 1.05
	III	0.581 ± 0.337	0.868 ± 0.809	0.623 ± 0.435
	IV	0.998 ± 0.65	0.533 ± 0.34	0.46 ± 0.164
Water silicate (µg at/l)	I	40.40 ± 12.45	60.89 ± 26.33	62.25 ± 21.18
	II	29.97 ± 1.96	7.00 ± 1	51.09 ± 12.06
	III	35.55 ± 9.59	36.25 ± 12.26	30.88 ± 14.63
	IV	38.04 ± 11.83	58.41 ± 27.40	44.77 ± 20.26
Chlorophyll a (mg/m3)	I	33.50 ± 25.93	44.21 ± 27.57	46.04 ± 25.76
	II	20.85 ± 9.95	31.75 ± 6.98	24.24 ± 7.21
	III	21,20 ± 36.26	36.21 ± 13.52	39.82 ± 24.79
	IV	26.01 ± 8.39	34.12 ± 12.61	18.85 ± 8.86
Chlorophyll b (mg/m3)	I	12.73 ± 9.32	26.94 ± 8.09	32.42 ± 15.61
	II	5.39 ± 8.36	13.85 ± 5.64	15.12 ± 6.35
	III	12.98 ± 15.09	16.99 ± 13.55	13.22 ± 9.30
	IV	10.60 ± 5.29	26.14 ± 14.52	11.82 ± 6.97
Chlorophyll c (mg/m3)	I	12.95 ± 8.24	29.90 ± 11.95	25.39 ± 17.7
	II	10.18 ± 4.27	15.28 ± 6.75	13.03 ± 9.13
	III	21.07 ± 13.96	32.06 ± 34.52	21.12 ± 16.62
	IV	16.5 ± 9.12	33.45 ± 30.41	19.32 ± 8.10
Carotenoid (mg/m3)	I	15.38 ± 11.86	12.09 ± 6.86	14.27 ± 6.13
	II	5.52 ± 1.65	10.03 ± 6.50	8.23 ± 7.56
	III	18.20 ± 14.37	18.75 ± 14.80	16.83 ± 12.52
	IV	15.76 ± 4.32	28.51 ± 11.84	11.99 ± 6.28

TABLE 3A - The mean ± S.D. of selected parameters in different centres seasonwise

Parameters	Centre	Premonsoon (April - May)	Monsoon (June - Sept.)	Postmonsoon (Oct. - Nov.)
Soil pH (Dry)	I	5.13 ± 0.32	3.95 ± 0.56	5.09 ± 0.49
	II	6.02 ± 0.26	5.54 ± 0.44	5.80 ± 0.41
	III	6.44 ± 0.644	5.69 ± 1.22	6.14 ± 0.86
	IV	5.52 ± 0.56	5.20 ± 0.42	5.45 ± 0.69
Soil pH (Wet)	I	7.16 ± 0.19	6.29 ± 0.40	6.43 ± 0.41
	II	7.90 ± 0.30	7.52 ± 0.18	6.87 ± 0.24
	III	7.85 ± 0.36	7.52 ± 0.47	7.18 ± 0.21
	IV	6.92 ± 0.25	6.58 ± 0.61	6.54 ± 0.18
Soil Eh (mv)	I	448 ± 40	345 ± 39	366 ± 38
	II	431 ± 51	353 ± 65	360 ± 77
	III	310 ± 42	351 ± 35	327 ± 50
	IV	350 ± 55	393 ± 76	398 ± 53
Soil Alkalinity (mg/gm)	I	1.29 ± 0.30	1.06 ± 0.61	0.858 ± 0.40
	II	2.03 ± 0.27	1.76 ± 0.14	1.586 ± 0.984
	III	5.29 ± 3.76	3.65 ± 2.40	6.43 ± 7.20
	IV	2.03 ± 1.05	2.10 ± 1.02	0.989 ± 0.716
Soil EC (mmho/cm)	I	7.8 ± 4.7	4.03 ± 2.04	3.07 ± 1.24
	II	6.83 ± 1.64	2.07 ± 0.72	2.47 ± 0.40
	III	11.85 ± 3.55	6.02 ± 5.18	4.93 ± 3.13
	IV	3.42 ± 0.54	1.22 ± 0.72	1.15 ± 0.57
Soil organic carbon (%)	I	1.687 ± 0.50	1.98 ± 0.64	1.037 ± 0.42
	II	0.978 ± 0.36	0.51 ± 0.08	1.182 ± 0.72
	III	1.064 ± 0.50	1.038 ± 0.84	1.134 ± 1.02
	IV	1.314 ± 0.40	1.12 ± 0.25	1.069 ± 0.47
Soil Available phosphate phosphorus (μg/gm)	I	272.25 ± 91.03	108.09 ± 33.89	82.81 ± 18.74
	II	45.68 ± 15.23	13.87 ± 5.18	63.89 ± 41.86
	III	30.50 ± 23.18	36.02 ± 30.87	36.56 ± 26.48
	IV	19.22 ± 6.61	17.10 ± 4.26	10.89 ± 4.53
Soil nitrate nitrogen (μg/gm)	I	9.58 ± 3.88	6.91 ± 2.70	7.68 ± 2.41
	II	5.25 ± 2.54	6.54 ± 1.68	5.82 ± 1.49
	III	13.40 ± 5.03	6.42 ± 1.88	9.86 ± 1.91
	IV	12.79 ± 3.14	7.79 ± 1.69	8.58 ± 2.55
Soil available sulphur (ppm)	I	1974.67 ± 991.50	1117.85 ± 145.24	471.56 ± 129.68
	II	962.50 ± 479.25	479.37 ± 308.85	369.64 ± 158.95
	III	1188.10 ± 478.70	520.52 ± 383.29	571.80 ± 257.88
	IV	310.00 ± 126.66	495.11 ± 317.78	594.94 ± 389.37
Soil TEC (me /100gm)	I	6.08 ± 2.93	6.93 ± 3.10	4.75 ± 1.32
	II	7.00 ± 2.46	5.02 ± 0.98	5.21 ± 2.34
	III	12.52 ± 10.06	11.98 ± 11.25	8.75 ± 8.18
	IV	3.82 ± 1.17	5.06 ± 4.18	3.27 ± 1.45
Soil CEC (me /100gm)	I	20.08 ± 4.59	18 ± 5.41	18.58 ± 6.27
	II	21.33 ± 2.06	20.33 ± 1.36	18.33 ± 0.81
	III	17.20 ± 7.06	19.1 ± 4.22	17.50 ± 4.85
	IV	20.7 ± 1.64	21.66 ± 3.70	20.78 ± 1.09
Soil exchangeable pottassium (ppm)	I	784.42 ± 543.09	429.50 ± 269.40	633.42 ± 381.74
	II	939.83 ± 105.27	658 ± 133.4	744.67 ± 151.11
	III	1291.20 ± 869.28	829.5 ± 523.29	1039.80 ± 730.72
	IV	261.78 ± 137.79	172 ± 85.17	189.89 ± 98.55
Soil exchangeable sodium (ppm)	I	1581.25 ± 785.25	856.5 ± 592.20	1138.17 ± 714.26
	II	2017.67 ± 150.46	1146.5 ± 190.01	1427.33 ± 201.87
	III	2843.50 ± 939.18	1522.1 ± 357.74	1861.20 ± 422.13
	IV	498.33 ± 286.21	329.8 ± 240.63	321.67 ± 201.72
Soil exchangeable calcium (ppm)	I	2071.67 ± 356.27	1253.1 ± 248.98	1407.42 ± 219.23
	II	2242.00 ± 247.90	1367.5 ± 276.26	1474.00 ± 275.71
	III	3400.90 ± 2145.57	2322.6 ± 1440.20	2412.90 ± 1549.94
	IV	1064.11 ± 355.45	687.2 ± 235.67	665.89 ± 227.34

TABLE 3b - The mean ± S.D. of Selected Parameters in different centres seasonwise

Light and Temperature

Light is a physical factor of importance, the penetration of which can be measured by the extent of turbidity. However, Secchi disc turbidity couldn't be measured always for all ponds since sometimes the ponds being shallow especially during low tides, disc becomes visible till the bottom of the pond. Turbidity was generally varying between 15cm to 70cm in these ponds.

Temperature of water during the period of study varied from 26°C to 33°C. Maximum temperature was recorded in premonsoon month of May while the minimum was recorded during monsoon month of July. Diurnal variation of 8.5°C was observed in May whereas only of 1.5°C variation was observed during July. Temperature of soil during the period of study ranged from 22°C to 26°C. Seasonal trend was similar to that of water temperature. Between the stations or even between the Centres, there was very marginal variation with respect to temperature.

Hydrogen ion concentration

In the present study the range of pH of water was found to be between 6.07 and 8.78 with minimum at Vyttila (Centre I) and maximum at Puthuvypeen (Centre III), both in post monsoon months with a mean of 7.39 $\pm$ 0.52. Similarly soil pH (wet) varied from 5.09 to 8.4 with minimum at Vyttila during monsoon and maximum at Puthuvypeen during premonsoon with a mean of 7.01 $\pm$ 0.62.

Table-4 Correlation between selected parameters of soil and water quality in culture ponds (pooled data)

Water pH

Vs water salinity r	: 0.429**	Chlorophyll a	: 0.242
Vs water alkalinity	: 0.51**	Chlorophyll b	: 0.005
Vs soil - pH	: 0.518**	Soil av. phosphorus	: 0.106
Vs soil-EC	: 0.436**	Soil organic carbon	: 0.164
Vs soil-alkalinity	: 0.545**	Soil nitrate	: 0.077
Vs soil clay	: 0.401**	Soil av. sulphur	: 0.236
Vs soil-exchang. K^+	: 0.396**		
Vs soil exchang. Na^+	: 0.424**		
Vs soil exchang. Ca^{++}	: 0.534**		
Vs water phosphate	: -0.23*		
Vs water nitrate	: -0.25*		

Water Salinity

Vs Water Hardness	: 0.392**	Water phosphate	: -0.229
Vs Water alkalinity	: 0.563**	Chlorophyll a	: 0.042
Vs Water nitrate	: -0.335**	Soil av.phosphorus	: 0.019
Vs water silicate	: -0.428**		
Vs chlorophyll - b	: -0.274**		
Vs soil EC	: 0.69**		
Vs soil exchang. K^+	: 0.617**		
Vs exchang. Na^+	: 0.745**		

Water alkalinity

Vs water nitrate	: -0.348**	Soil organic carbon	: 0.15
Vs water silicate	: -0.316**	Soil av. phosphorus	: -0.163
Vs chlorophyll a	: 0.221*	Soil nitrate	: 0.185
Vs soil pH	: 0.476**	Soil av.sulphur	: 0.091
Vs soil EC	: 0.453**		
Vs soil alkalinity	: 0.783**		
Vs soil C E C	: -0.546**		
Vs soil T E C	: 0.583**		
Vs soil clay	: 0.45 **		
Vs soil exchang.K^+	: 0.554**		

Water phosphate

Vs water nitrate	: 0.428**	water salinity	: -0.229
Vs chlorophyll a	: 0.206*	chlorophyll c	: 0.08
Vs chlorophyll b	: 0.451**	soil C E C	: -0.025
Vs soil pH	: -0.302**	soil T E C	: -0.076
Vs soil Av. phosphorus	: 0.506**	soil clay	: -0.108
Vs soil sulphur	: 0.313**	soil nitrate	: 0.03
Vs soil organic carbon	: 0.33		

Water nitrate

Vs chlorophyll a	: 0.269**	Soil Ec	: 0.095
Vs chlorophyll b	: 0.451**	soil sulphur	: 0.148
Vs chlorophyll c	: 0.327**	soil nitrate	: -0.077
Vs soil pH	: 0.215*		
Vs soil organic carbon	: 0.247**		

Chlorophyll a

Vs soil organic C	: 0.294**	soil av.phosphorus	: 0.172
Vs soil exchang. K^+	: 0.409**	soil nitrate	: -0.007

Chlorophyll b

Vs soil organic carbon	: 0.336	soil av.phosphrus	: 0.102
Vs soil exchang.K^+	:	soil nitrate nitrogen	: -0.14
		soil av.sulphur	: 0.103

Chlorophyll c

Vs soil alkalinity	: 0.418**	soil av.phosphorus	: -0.004
Vs soil T E C	: 0.577**	soil nitrate nitrogen	: -0.132
Vs soil clay	: 0.367**	soil sulphur	: -0.008
Vs soil organic C	: 0.345**		

Water silicate

Vs water salinity	: -0.428**	soil clay	: -0.161
Vs soil pH	: 0.298**	soil organic carbon	: 0.001
		soil av.phosphorus	: 0.020
		soil nitrate	: -0.182
		soil available sulphur	: -0.147

* Significant at 5% level.
** Significant at 1% level.

	Soil pH	S.EC	S.alk	S.CEC	S.TEC	S.Clay	S.OrgC	S.OrgC	S.AV phos.	S. Sulphur	S.K+	S.Na+	S.Ca++
Soil pH	-												
	**												
S.EC	0.546	-											
	**	**											
S.alk	0.436	0.486	-										
	**	**	**										
S.CEC	-0.261	-0.394	-0.607	-									
	**	**	**	**									
S.TEC	0.494	0.678	0.737	-0.666	-								
	**	**	**	**	**								
S.clay	0.258	0.569	0.623	-0.537	0.713	-							
			**	**	**	**							
S.orgC	0.099	0.287	0.296	-0.356	0.427	0.306	-						
		**				**	**						
S.A.V.Phos	-0.072	0.292	-0.074	-0.085	0.044	0.281	0.38	-					
S.Nitrate	0.112	0.165	0.066	0.076	-0.007	-0.046	000	0.023	-				
					*	**	**	**					
S.Sulphur	0.143	0.469	0.114	-0.17	0.24	0.335	0.471	0.753	0.071	-			
	**	**	**	**	**	**		*					
S-K	0.495	0.717	0.657	-0.584	0.737	0.772	0.179	0.188	0.100	0.300	-		
	**	**	**	**	**	**				**	**		
S-Na+	0.565	0.753	0.479	-0.367	0.519	0.571	-0.004	0.162	0.098	0.305	0.761	-	
	**	**	**	* *	**	**	**			**	**	**	
S-Ca++	0.612	0.745	0.748	-0.667	0.828	0.715	0.296	0.179	0.028	0.366	0.818	0.726	-

TABLE 5 - Correlation matrix between soil parameters in culture ponds (pooled data)

* ---- Significant at 5% level
** ---- Significant at 1% level
S. ---- Soil

Table - 8 Variation in Soil pH (wet & Dry, soil Eh, Water Ph & Dissolved Oxygen in different stations season wise.

	PRE-MONSOON					MONSOON					POST-MONSOON				
ation	Soil pH (Wet)	Soil pH (Dry)	Soil Eh	Water pH	Diss-olved oxygen	Soil pH (Wet)	Soil pH (Dry)	Soil Eh	Water pH	Diss-olved oxygen	Soil pH (Wet)	Soil pH (Dry)	Soil Eh	Water pH	Dissolved oxygen
1	7.41	4.93	442	7.39	2.57	6.47	3.45	384.3	7.22	2.29	6.56	5.52	386.66	6.63	2.12
2	7.06	5.09	478.5	7.78	3.67	6.11	3.84	339	7.44	3.03	6.64	4.82	416.00	6.811	2.45
3	7.08	5.38	394.7	7.59	2.98	6.44	4.58	317.7	7.42	2.27	5.85	5.20	354.66	6.23	2.31
4	7.98	5.94	402.3	7.56	4.5	7.37	5.42	393.3	7.20	3.15	6.77	5.69	347.00	7.44	2.04
5	7.80	6.2	459.7	7.49	4.17	7.66	5.68	312.6	7.33	2.1	6.95	5.99	374.00	7.33	2.10
6	7.74	5.82	318.7	7.45	3.0	7.09	5.35	383	7.50	3.93	7.02	5.82	341.66	4.48	2.90
7	7.46	6.09	282.7	7.43	2.77	7.24	5.35	383	7.53	3.83	7.06	5.92	309.00	7.87	3.9
8	8.22	7.15	325	8.18	4.3	8.04	6.79	355	7.68	4.75	7.37	7.20	328.75	8.39	5.6
9	7.03	5.41	360.7	7.73	3.13	7.04	5.56	393.3	7.63	2.1	6.45	5.08	390.33	6.54	2.09
10	6.60	4.98	405.7	7.20	3.1	6.14	4.42	460.3	7.29	2.87	6.57	5.18	454.00	6.7	4.62
11	7.13	6.18	283.7	7.12	3.53	6.56	5.62	324	7.62	2.9	6.61	6.1	349.66	7.04	2.19

A highly significant positive correlation was observed between pH of soil and that of water ($r=0.518$ at $p < 0.01$). Dry soil pH was found to be between 3.53 and 7.28 and with a overall mean of 5.5 ± 0.64. The difference between soil dry pH & wet pH was found to be soil specific to some extent. Centre II and III are having comparative less difference between dry and wet pH whereas centre I and IV have a wider gap. However, there was a positive correlation significant at 1% level between the dry and wet pH of soil.

Water pH showed positive correlation with water salinity, water alkalinity, soil EC, soil alkalinity, soil clay and exchangeable K^+, Na^+, Ca^{++}, all significant at 1% level 'r' being 0.429, 0.51, 0.436, 0.535, 0.401, 0.396, 0.424 and 0.536 respectively (Table 4). Both soil and water pH were negatively correlated with water phosphate [$r=-0.302$ ($p < 0.01$) and -0.23 ($p < 0.05$ respectively] and with water nitrate also ($r=-0.215$ and -0.253, both significant at 5% level).

A highly significant positive correlation was found to exist between soil pH and soil EC ($r=0.546$ at 1% level), exchangeable K^+, Na^+ and Ca^{++} ($r=0.495$, 0.565 and 0.612 at 1% level respectively). With soil alkalinity it also showed positive correlation having 'r'=0.436 and with soil TEC 'r'=0.494 at $p < 0.01$. However, very poor correlation was observed between soil pH and organic carbon, available sulphur of soil (Tabel 5).

Two way Analysis of variance (ANOVA) tables showing the level of significance in variation of different parameters among centres and over seasons. (Table 10-28)

Table 10 **Water-pH**

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replication	5	0.681	0.136	0.9563
Centres	3	4.394	1.465	10.2787 **
Error	15	2.138	0.143	
Seasons	2	3.270	1.635	20.4409 **
Interactions	6	6.357	1.060	13.2447 **
Error	40	3.200	0.080	
Total	71	20.041		

Table 11 **Soil pH**

Source	D.F.	Sum of Square	Mean Square	F Value
Replication	5	0.765	0.153	0.8969
Centres	3	12.481	4.160	24.3998 **
Error	15	2.558	0.171	
Seasons	2	7.210	3.605	33.0052 **
Interactions	6	1.431	0.239	2.1836
Error	40	4.369	0.109	
Total	71	28.814		

Table 12

Water Phosphate

Source	D.F	Sum of Squares	Mean Square	F Value
Replication	5	1004.16	200.83	1.023
Centres	3	7993.36	2664.45	13.571 **
Error	15	2944.96	196.33	
Season	2	51.17	25.58	0.616
Interaction	6	956.74	159.45	3.840 **
Error	40	1661.16	41.53	
Total	71	14611.542		

Table - 13

Soil Available Phosphorus

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	5	1422.36	284.47	0.7357
Centres	3	5948.43	1982.81	5.128 *
Error	15	5799.99	386.67	
Seasons	2	8579.05	4289.53	20.8553
Interaction	6	4095.38	682.56	3.3186 **
Error	40	8227.20	205.68	
Total	71	34072.20		

Table 14 Water nitrate

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	5	809.76	161.95	1.043
Centres	3	8426.85	2808.95	18.094 **
Error	15	2328.66	155.24	
Seasons	2	1725.86	862.93	8.056 **
Interaction	6	5354.06	892.34	8.330 **
Error	40	4284.87	107.12	
Total	71	22930.07		

Table 15
Soil nitrate

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replication	5	40.41	9.28	0.8485
Centres	3	232.22	77.40	7.0760**
Error	15	164.09	10.93	
Seasons	2	190.84	95.42	1.987 **
Interaction	6	143.97	23.99	4.9990**
Error	40	192.00	4.80	
Total	71	969.55		

Table 16

Soil Cation exchange capacity.

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replication	5	142.17	28.43	1.69
Centres	3	72.78	24.26	1.44
Error	15	252.39	16.83	
Seasons	2	17.58	8.79	1.83
Interactions	6	41.31	6.88	1.44
Error	40	191.78	4.79	
Total	71	718.00		

Table: 17

Soil Total Exchangeable Metallic Cations

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	5	466.314	93.263	1.4260
Stations	3	324.368	108.123	1.6533
Error	15	980.999	65.400	
Seasons	2	44.203	22.101	3.8090*
Interactions	6	24.718	4.120	0.7100
Error	40	232.094	5.802	
Total	71	2072.696		

Table: 18

Soil Organic Carbon

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replication	5	0.918	0.184	0.2976
Centres	3	2.627	0.876	1.4191
Error	15	9.255	0.617	
Seasons	2	0.174	0.087	0.3840
Interactions	6	5.059	0.843	3.7134**
Error	40	9.082	0.227	
Total	71	27.115		

Table: 19

Soil Available Sulphur:-

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replication	5	989488.40	197897.68	0.9948
Centres	3	2637018.03	879006.00	4.4184*
Error	15	2984116.58	198941.11	
Seasons	2	2944004.00	142002.00	17.9716**
Interactions	6	2995481.50	499246.93	6.0953*
Error	40	3276287.58	81907.19	
Total	71	15826396.192		

Table: 20

Soil Exchangeable Potassium

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	5	3642996.903	728599.381	2.1979
Centres	3	5165431.829	1721810.606	5.1939*
Error	15	4972574.264	331504.951	
Seasons	2	732781.361	366390.681	25.2161**
Interactions	6	132348.972	22058.162	1.5181
Error	40	581200.333	14530.008	
Total	71	15227333.653		

Table: 21

Soil exchangeable Sodium

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	5	1108116.569	2221623.314	4.0420
Centres	3	31529858.042	10509952.681	19.1217**
Error	15	8244535.042	549635.669	
Seasons	2	7976993.694	3988496.847	43.2167**
Interactions	6	2309164.417	384860.736	4.1701
Error	40	3691624.556	92290.614	
Total	71	64860292.319		

Table: 22

Soil exchangeable Calcium

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	5	17865737.79	3573147.558	1.6036
Centres	3	25258649.708	8519549.903	3.7786*
Error	15	33423254.375	2228216.958	
Seasons	2	8954316.750	4477158.375	82.5889**
Interactions	6	676353.583	112725.597	2.0794
Error	40	2168407.667	54210.192	
Total	71	88346719.875		

Table: 23

Chlorophyll -a

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replications	5	577.265	115.453	0.2977
Centres	3	533.668	117.889	0.4587
Error	15	5816.918	387.795	
Seasons	2	1102.259	551.130	3.0299*
Interation	6	1310.323	218.387	0.3260
Error	40	7275.898	181.897	
Total	71	16616.332		

Table: 24

Chlorophyll -b

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replication	5	564.060	112.812	0.5080
Centres	3	1089.49	363.163	1.6354
Error	15	3331.00	222.067	
Seasons	2	1515.48	757.740	9.6304**
Interactions	6	1538.96	256.494	3.2599*
Error	40	3147.29	78.682	
Total	71	11186.28		

Table: 25

Chlorophyll -c

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replication	5	1307.92	261.585	0.3322
Centres	3	1704.744	598.248	0.7598
Error	15	11810.573	787.372	
Seasons	2	3693.677	1846.838	11.0521**
Interactions	6	1185.708	197.618	1.1826
Error	40	6084.129	167.103	
Total	71	26476.755		

Table: 26

Water Carotenoid.

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	6	137.432	27.486	0.0905
Centres	3	1266.926	422.309	1.3899
Error	15	4557.533	303.836	
Seasons	2	586.122	293.061	5.9047**
Interactions	6	987.432	164.572	3.3158**
Error	40	1985.281	49.632	
Total	71	9520.726		

Table: 27

Water Silicate

Source	D.F.	Sum of Squares	Mean Squares	F Value
Replications	5	1422.357	284.471	0.7357
Centres	3	5948.433	1982.811	5.1280*
Error	15	5799.996	386.666	
Seasons	2	8579.054	4289.527	20.8553**
Interaction	6	4095.381	682.563	3.3186**
Error	40	8227.201	205.680	
Total	71	34072.424		

Table: 28

Water Salinity

Source	D.F.	Sum of Squares	Mean Square	F Value
Replication	5	48.024	9.605	0.9314
Centres	3	1203.520	401.173	38.9024**
Error	15	154.684	10.312	
Seasons	2	2294.959	1147.480	290.3536**
Interactions	6	843.672	140.612	35.5799**
Error	40	158.08	3.952	
Total	71	4702.941		

* Significant at 1% level
** significant at 5% level

Two way ANOVA (Table 10) shows that between centres there was significant difference in water pH at 1% level. Similarly between seasons also there exists variations in water pH at 1% level. Further, interaction between the centres and seasons also showed highly significant difference at 1% level.

Two way ANOVA for soil pH (Table 11) shows that the values were differing significantly between centres and also between seasons at 1% level. However, interaction between centres and seasons didn't show any significant variation with respect to soil pH.

The range and average of soil and water pH in different centres seasinwise is given in Table 2 & 3. Decrease in pH values was observed with the onset of monsoon and continued till the postmonsoon. Among the centres, centre III always showed higher range of pH (7.18 to 7.85) followed by centre II (6.87 to 7.90). In both hydromorphic saline and acid saline soils of centre I & IV, it was comparatively low.

Redox Potential

The Redox Potential (Eh) of soil varied from +228 mv to +549 mv with an overall mean of 368.79 $\pm$ 62.89.

Centre I and IV showed relatively high Eh than that of centre II & III. The range and mean of each centre seasonwise is given in Table 2 & 3. The mean value of Eh for premonsoon, monsoon and postmonsoon were respectively 384 $\pm$ 74.21, 370 $\pm$ 54 and 362 $\pm$ 57. No common trend was observed with respect to seasons. In first two centres, it was declining whereas in the other two it was increasing during monsoon.

Dissolved Oxygen

Dissolved oxygen fluctuated from as low as 0.7 ml/l at Vennala (station-1) to as high as 7.65 ml/l at Puthuvypeen (station - 8), both during post monsoon months. It varied between 1.35 ml/l to 5.55 ml/l during premonsoon, 1.8 to 4.92 ml/l during monsoon, and 0.7 ml/l to 7.55 ml/l during postmonsoon months.

Dissolved oxygen was found to be correlated with pigments, 'r' being 0.62 significant at 1% level. Dissolved oxygen was found to vary from pond to pond and from season to season. Diurnal variations also well observed in these ponds. Table 8 shows the variation of dissolved oxygen in different stations seasonwise.

Salinity

Water salinity varied between 0.08 ppt and 27 ppt with an overall mean of 5.93 $\pm$ 8.01 ppt, the highest value being observed at Puthuvypeen (station -8) during premonsoon and the lowest being observed at Karumudy (station-10) during monsoon months.

Fig. 4

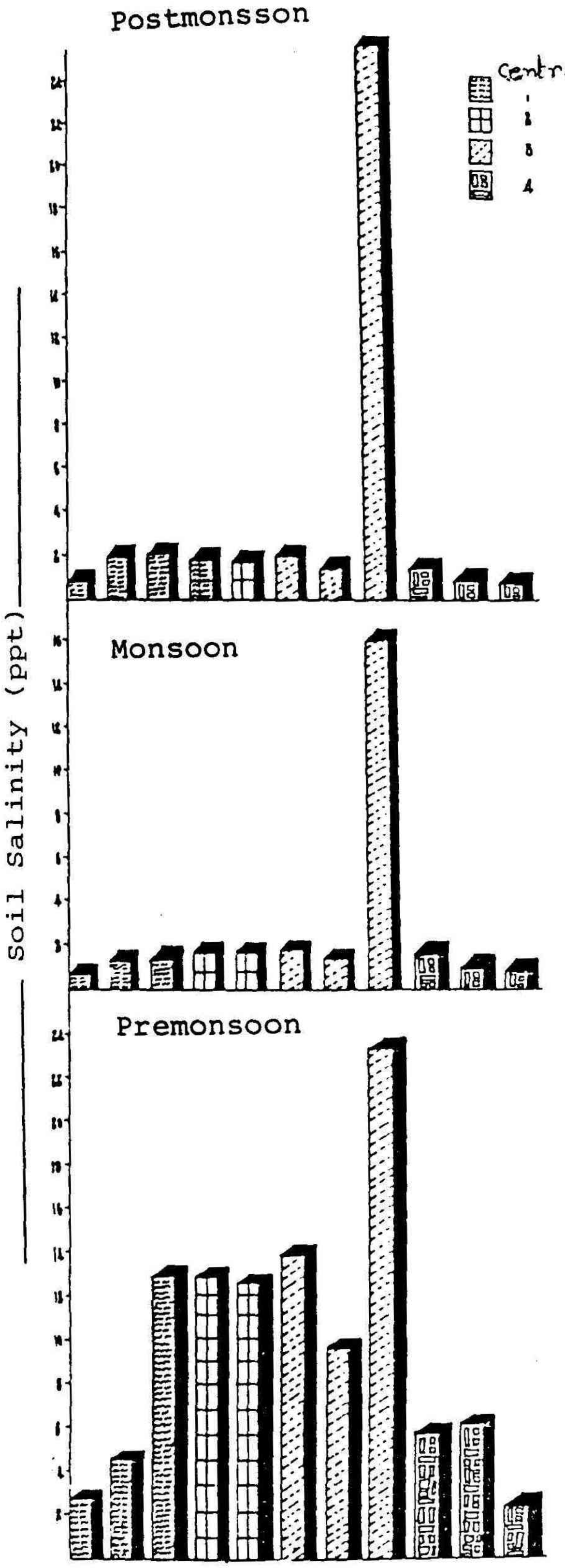
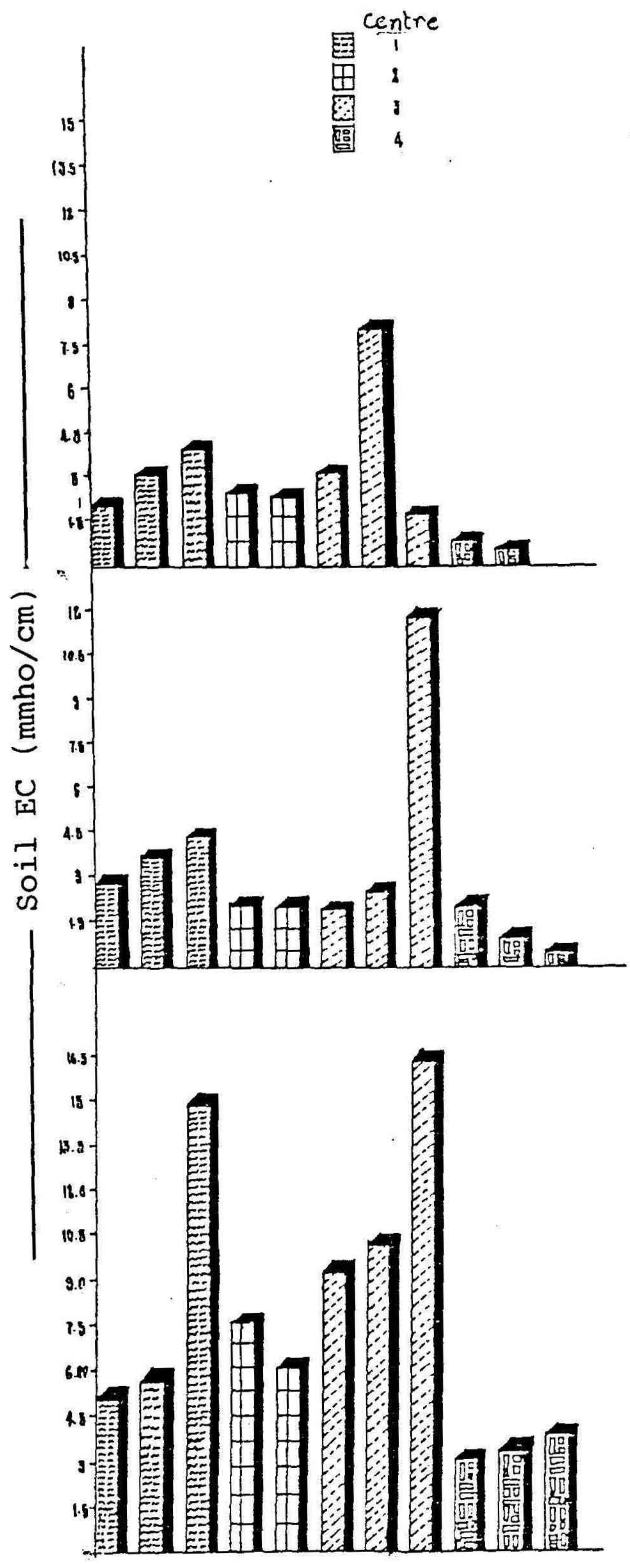


Fig. 5



STATIONS

Fig. 4 Seasonal variation in Soil Salinity in different stations

Fig. 5 Seasonal variation in Soil EC in different stations

TREND IN ALKALINITY
IN DIFFERENT SEASON

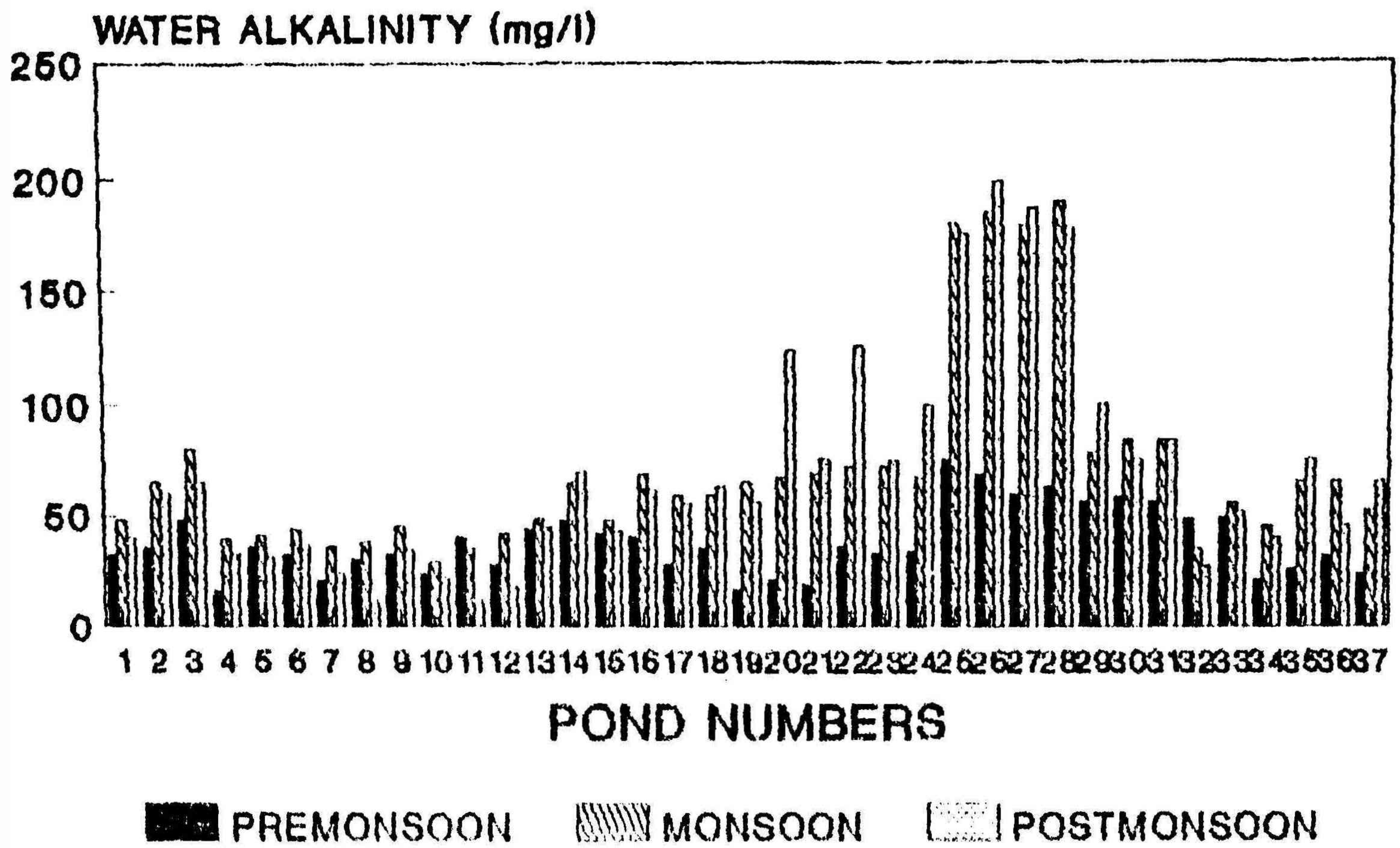


Fig. 6

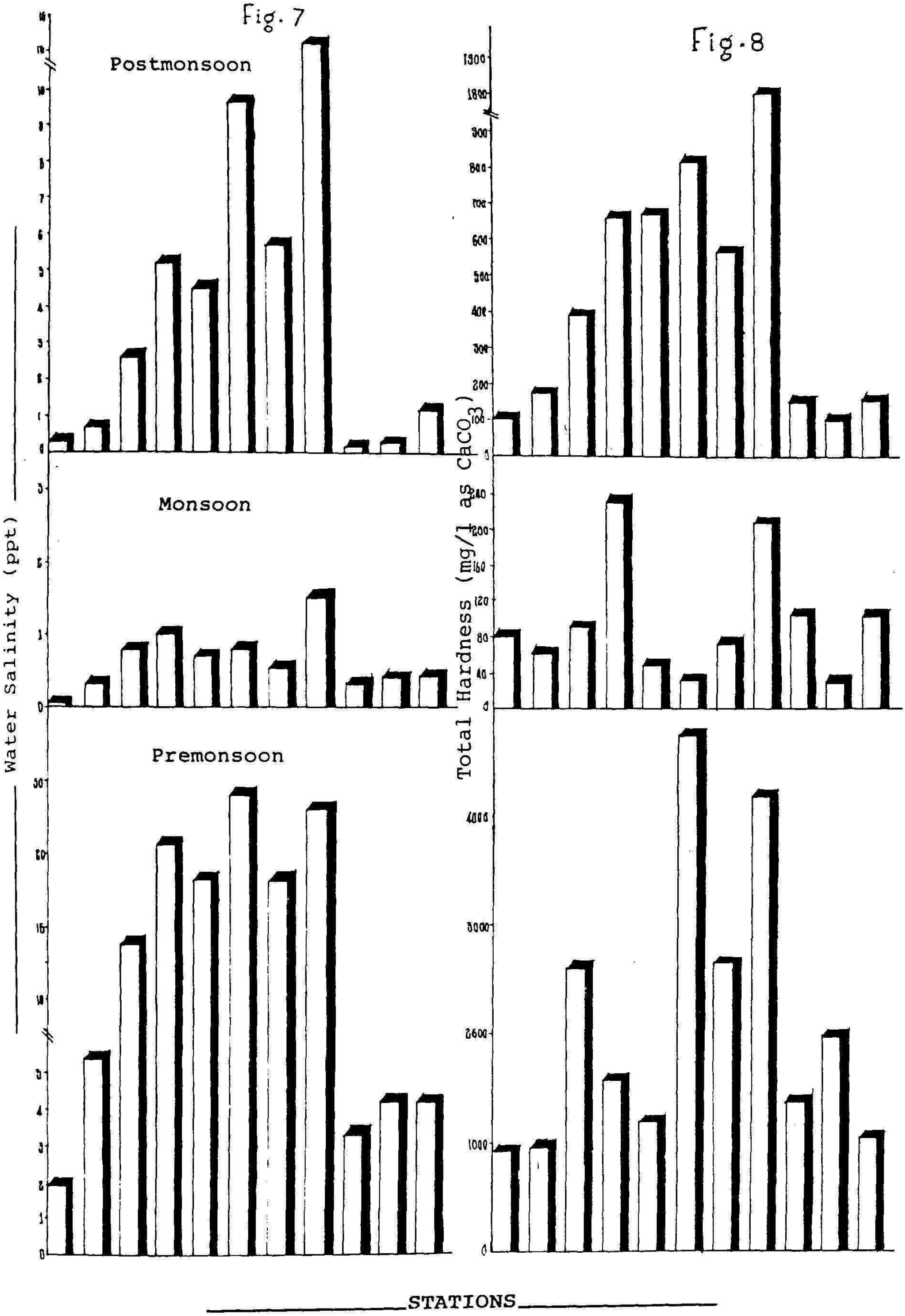


Fig. 7 Seasonal variation in Water Salinity in different stations

Fig. 8 Seasonal variation in Total Hardness of water in different stations

Soil salinity varied between 0.46 ppt and 27.67 ppt. It showed highly significant correlation with water salinity (Fig 4). Water salinity showed highly significant correlation with soil exchangeable cations like K^+ (r=0.617), Na^+ (r=0.745), Ca^{++} (r=0.594) and with soil conductivity (r=0.69) all significant at 1% level. Also significant correlation was observed between salinity and hardness of water and between salinity and alkalinity of water ($p < 0.01$). However, salinity has an inverse correlation with water nitrate (r=-0.335) and water silicate (r=-0.428) and chlorophyll b (r=-0.274) all significant at 1% level. No significant correlation was established between salinity and water phosphate, chlorophyll a and soil phosphate ($p < 0.05$).

Two way ANOVA reveals that there was significant variation in salinity of water between stations and also between seasons. Further, the interation between seasons and centres also shows significant variation at 1% level (Table-28). The range and average with standard deviation for each centres seasonwise is given in Table 2 & 3. Within seasons, higher salinity was observed in all stations during premonsoon which fell drastically with the onset of monsoon and again increased in the early postmonsoon months.

Among the centres, centre III showed high salinity ranges in all seasons followed by centre II. This may be due to it's closure approach to the sea.

Total Hardness

Total hardness of water varied from 27.03 mg/l as $CaCO_3$ at Karumady (station 10) during monsoon to 4838 mg/l as $CaCO_3$ at Puthuvypeen (station 8) during premonsoon with an overall mean of 1110.36 $\pm$ 2594.7 mg/l as $CaCO_3$.

From the correlation analysis (Table-4) it is clear that total hardness showed a positive correaltion with water salinity, soil EC, soil clay and soil silt all significant at 1% level. However, with soil CEC it showed a significant negative correlation (r=-0.445) at 1% level.

Two way ANOVA showed that there was variation in water hardness between centres and also among seasons. Seasonal trend (Table-2 & 3) showed that in monsoon there was a decrease in total hardness value, which however again increased during postmonsoon months. Among the centres again, centre II and III showed high total hardness and centre I and IV showed comparatively low in all the seasons. Stationwise variation in total hardness is shown in Fig. 7.

Soil Conductivity

Conductivity of soil (EC) observed during the study ranged from 0.5 mmho/cm at Karumady (station 10) during monsoon to 18 mmho/cm at Puthuvypeen (station 8) during premonsoon with an overall mean of 4.75 $\pm$ 4.00 mmho/cm.

The range of soil EC in each centre is given in Table 2 and average with S.D. for each centre seasonwise is given in Table 3. Stationwise soil EC from season to season is shown in Fig. 5.

Seasonwise, premonsoon recorded the highest soil EC and monsoon the lowest and stationwise, Puthuvypeen (station 8) always recorded highest soil EC irrespective of seasons.

Soil EC showed a positive significant correlation with soil salinity (r=0.69), soil pH (r=0.546), soil TEC (r=0.678), soil available sulphur (r=0.469) and with available phosphorus (r=0.292) all significant at 1% level (Table 5). Soil EC also showed a good correlation with that of exchangeable cations like K^+, Na^+ and Ca^{++}. However, very poor correlation was found to exist between soil EC and organic carbon and also between soil EC and soil nitrate.

Alkalinity

Alkalinity or acid combining capacity of these brackishwater ponds are generally caused by carbonate and bicarbonate of calcium and magnesium. However, bicarbonate alkalinity was dominant in most of the ponds in the present study whereas carbonate fraction is meagre and found only in coastal alluvium soil of Narakkal and Puthuvypeen.

Water alkalinity range was found to be between 12 mg/l as

$CaCO_3$ at Vyttila (station 2) during post monsoon and 185 mg/l as $CaCO_3$ at Puthuvypeen (station 8) during premonsoon, with an overall average value of 59.24 $\pm$ 41.14 mg/l as $CaCO_3$. Soil alkalinity (mostly bicarbonate alkalinity) was found to be between 0.29 mg/gm at Vennala (station 1) and 17.05 mg/gm at Puthuvypeen (station 8), both during monsoon.

Between alkalinity of soil and water, a very good positive correlation with r=0.783 significant at 1% level was observed (Table 4). Water alkalinity also showed highly significant negative correlation with water nitrate, water silicate and soil CEC. However, positive significant correlation was established between water alkalinity and soil EC (r=0.453), soil TEC (r=0.583) and soil exchangeable K^+ (r=0.554) all significant at 1% level and with chlorophyll a (r=0.221) significant at 5% level.

A very poor correlation was found between alkalinity and organic carbon. Similarly with soil nutrients also soil alkalinity showed poor correlation. Soil alkalinity also recorded highly significant positive correlation (Table 5) with soil TEC (r=0.737), soil clay (0.623) and with exchangeable cations (r=0.657, 0.479 and 0.748 respectively with K^+, Na^+, Ca^{++}).

There was variation in alkalinity of both soil and water between centres and also between seasons. The range and mean $\pm$ S.D. is given in Table 2 & 3. Within a season, between the centres and within a centre, between the seasons also there was signifiant variation in alkalinity content. Seasonal trend showed a general decrease in alkalinity of water and soil during monsoon in all the centres. In postmonsoon months again the total alkalinity showed an increasing trend.

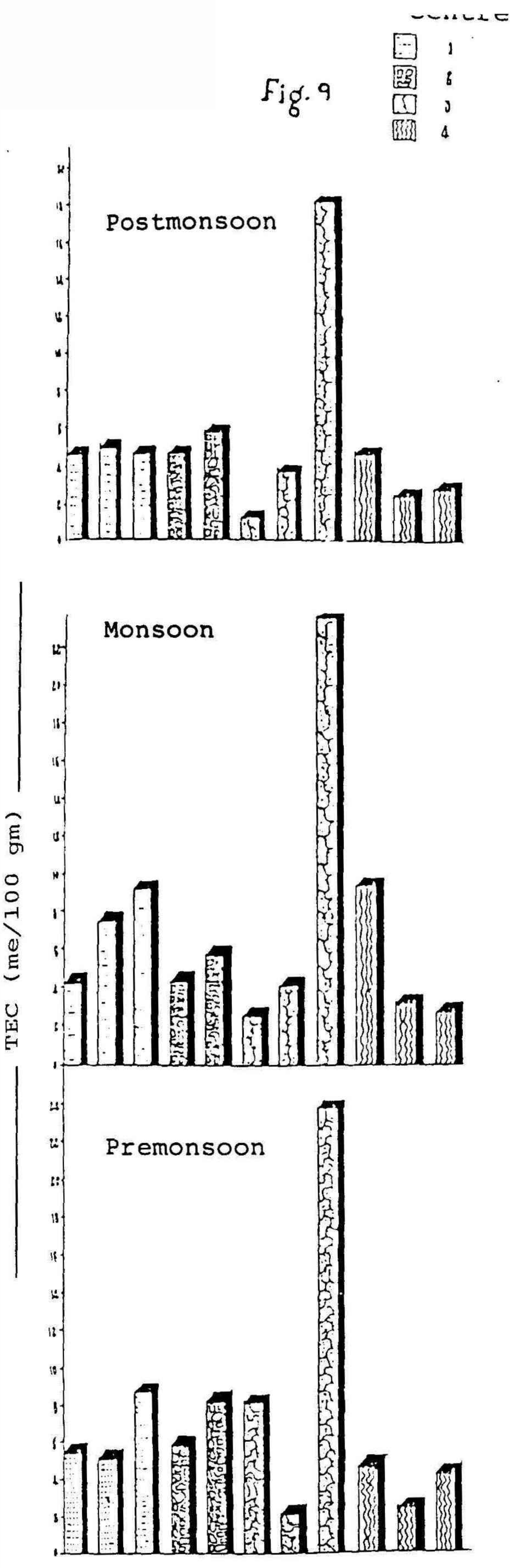
Among the stations, centres III always lead and centres I always lagged in the total alkalinity content of water and soil (Table 2 & 3). Stationwise variation in water alkalinity is shown in Fig. 6.

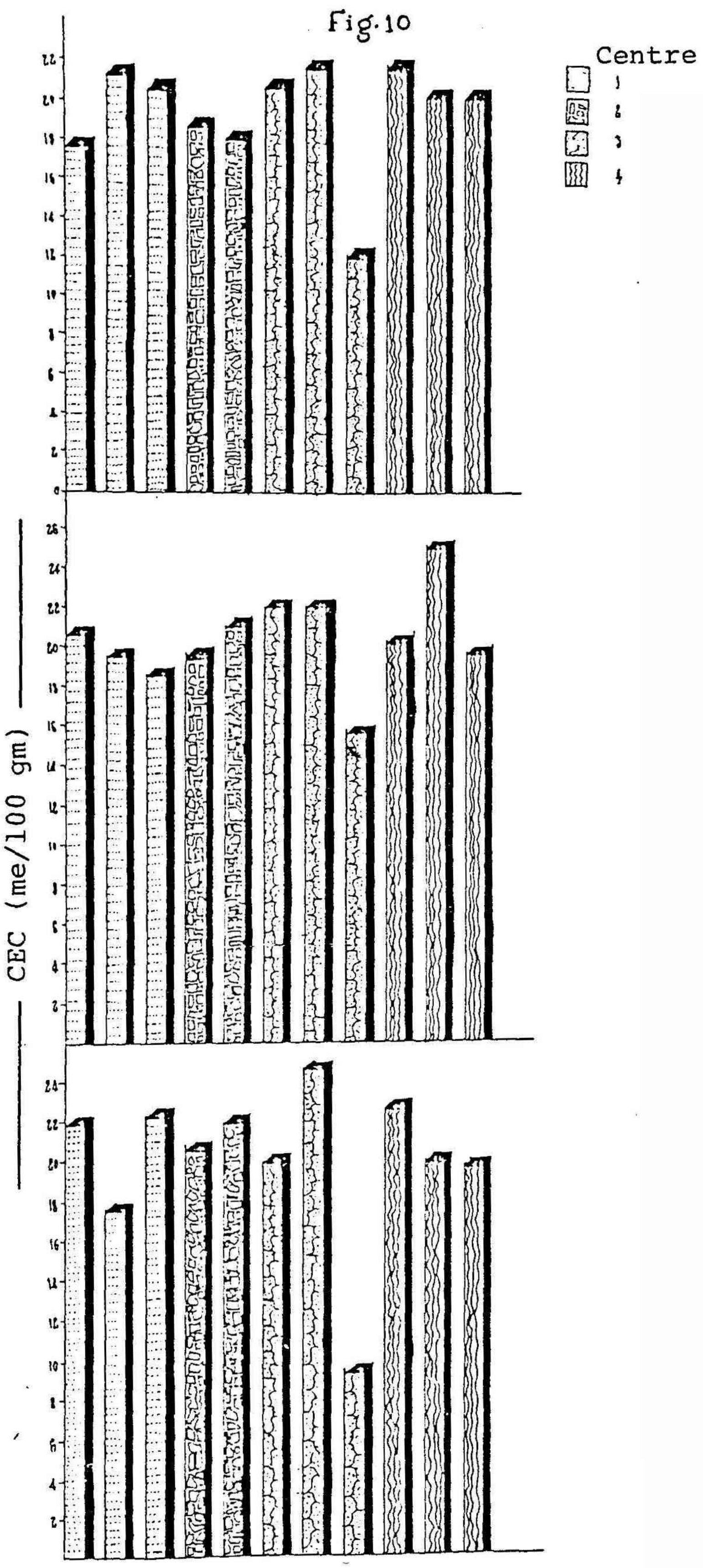
Cation Exchange Capacity

CEC of soil in the present study ranged from 6 to 28 me/100 gm with the lowest at Puthuvypeen (station 8) during premonsoon and the highest at Karumady (station 10) during monsoon and with an overall mean value of 19.68 $\pm$ 3.82 me/100 gm. CEC showed an inverse relation with soil pH ($r=-0.261$ at $P < 0.01$ and also with soil alkalinity ($r=-0.607$ at $P < 0.01$) in all seasons pooled together.

The range and mean $\pm$ S.D. of CEC for all stations seasonwise is given in Table 2 & 3. Stationwise variation in different seasons is shown in Fig. 10.

Two way ANOVA (Table 16) shows that there was no significant variation between the centres. However, there was significant variation in CEC values between the seasons at 5% level. Interactions between seasons and centres showed no variation in CEC of soil.





STATIONS

Fig. 9. Seasonal variation in soil TEC in different stations

Fig. 10. Seasonal variation in soil CEC in different stations

Among the centres , centre II & IV showed higher CEC (mean being 21.33 and 21.66 me/100 gm respectively) and centre III, the lowest (mean 17.2 me/100 gm). No definite pattern of increase or decrease was observed between the seasons. centre I and II showed a decrease whereas centres III & IV showed an increase of CEC during monsoon.

Total exchangeable metallic cations

TEC showed a variation from 0.88 me/100 gm at Cherai (station 6) during postmonsoon to 26.2 me/100 gm at Puthuvypeen (station 8) during monsoon with an overall mean of 6.83 $\pm$ 6.07 me/100 gm. Stationwise variation in TEC is given in Fig. 9. The range and mean $\pm$ S.D. of TEC in different stations seasonwise is given in Table 2 & 3.

TEC showed significant positive correlation with soil pH, soil alkalinity, soil K^+ ($r=0.737$ at $P < 0.01$) Na^+ ($r=0.519$ at $P < 0.01$) and Ca^{++} ($r=0.828$) and with organic carbon ($r=0.427$ at $P < 0.01$). But poor correlation was obtained with soil available phosphorus, nitrate and available sulphur (Tabel 5).

ANOVA reveals that there was no significant variation in soil TEC values between centres However, variation at 5% level exist between seasons. Further, interaction between seasons and centres i.e. within a season, between the centres and within a centre between the seasons there exist no significant variation (Table 17).

It is observed that total exchangeable metallic cations considerably increased in the Ist and the IVth centres, but in alluvial soil of centre II and III there was a decreasing trend during monsoon.

Exchangeable Potassium, Sodium & Calcium

In the present investigation exchangeable K^{+}, Na^{+} and Ca^{++} in soil was found to range from 55 to 2819 ppm, 113 to 4575 ppm and 320 to 6870 ppm respectively with the lowest value being observed at Karumady and Vechoor (station 9) during monsoon and the highest at Puthuvypeen (station 8) during premonsoon and having an overall mean of 661 $\pm$ 546.7, 1289 $\pm$ 890.5 ppm and 1715.36 $\pm$ 1188.69 ppm respectively.

The range and mean $\pm$ S.D. for each station, seasonwise as given in the Table 2 & 3, showed centre III with the highest cations and centre IV having the lowest. Stationwise variation for these cations in each season is given in Fig. 11. The exchangeable K^{+}, Na^{+} and Ca^{++} showed positive correlation, signifcant at 1% level with water salinity. Similarly positive correlation was observed between these cations and soil pH where Ca^{++} showed the best correlation with $r=0.612$ at $P < 0.01$.

These exchangeable cations were found to be significantly correlated with soil EC, soil clay, soil TEC and soil alkalinity (Table 5). The exchangeable K^{+} & Ca^{++} showed positive correlation with $r=0.409$ and 0.39 significant at 1% level with

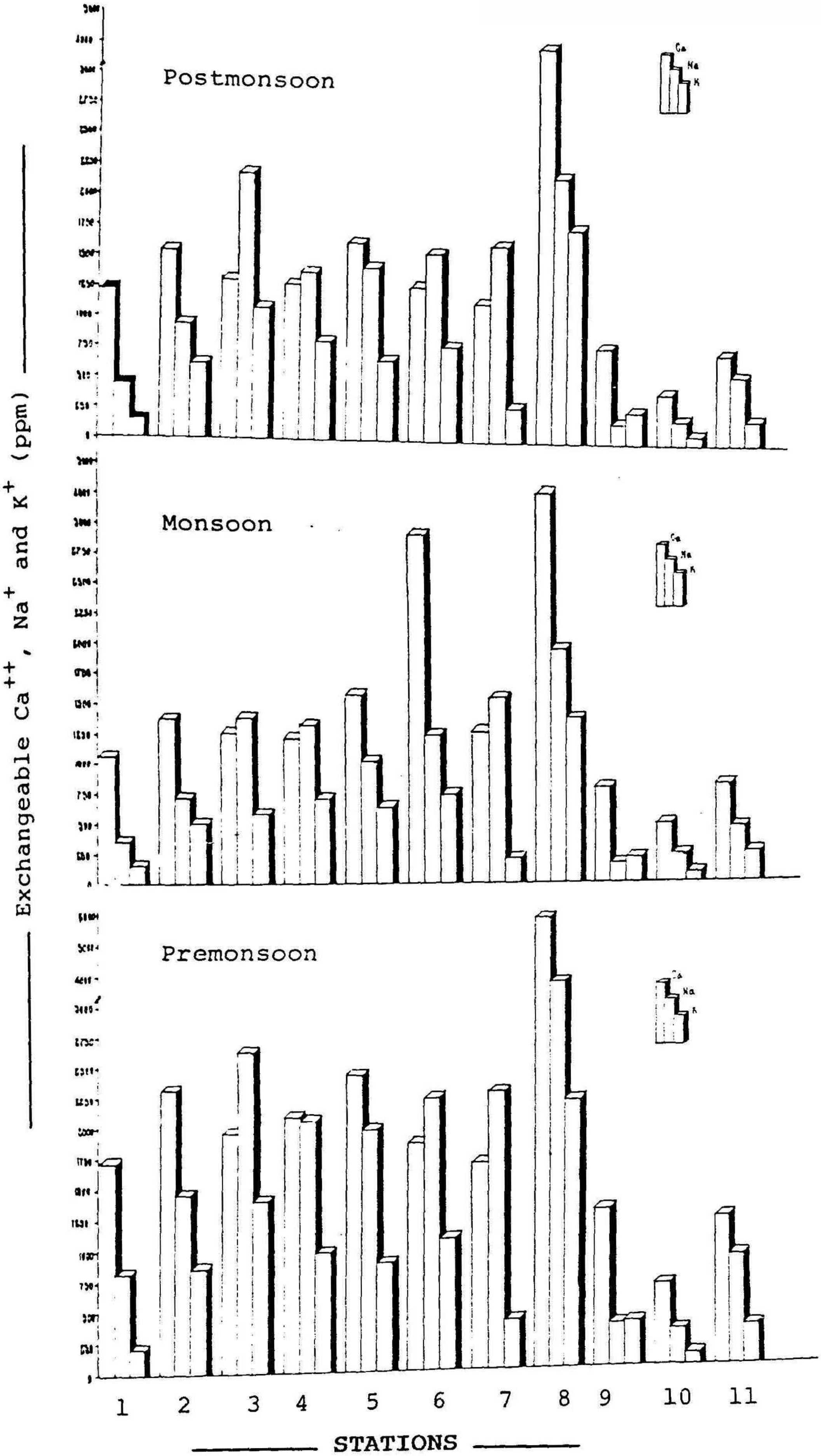


Fig. 11. Seasonal variation in Exchangeable Ca^{++}, Na^{+}, K^{+} in different stations

chlorophyll a, whereas exchangeable Na^+ was found to have poor correlation with this pigment (r=0.21 significant at 5% level).

ANOVA shows that there was significant variation between centres and also between seasons. However, it is clear that seasons had greater impact on cation mobility and availability. Again interaction between centres and seasons showed no remarkable variation in the value of exchangeable K^+, Na^+ & Ca^{++} (Table 20, 21 &22).

Organic Carbon

In the present study, soil organic carbon varied between 0.15 and 3.0% with the lowest value observed at Cherai (station 6) during postmonsoon and the highest at Vyttila (station 2) during monsoon.

The range and mean $\pm$ S.D for different stations seasonwise is given in Table 2 & 3. Fig. 12 shows the variation in organic carbon in different stations. The overall mean for organic carbon was found to be 1.23 $\pm$ 0.66 in the pooled data over all stations and seasons.

Soil organic carbon was found to have significant positive correlation with water reactive phosphorus (r=0.33), water nitrate (r=0.247), chlorophyll a (r=0.294), chlorophyll b (r=0.345) and with carotenoid, all being significant at 1% level.

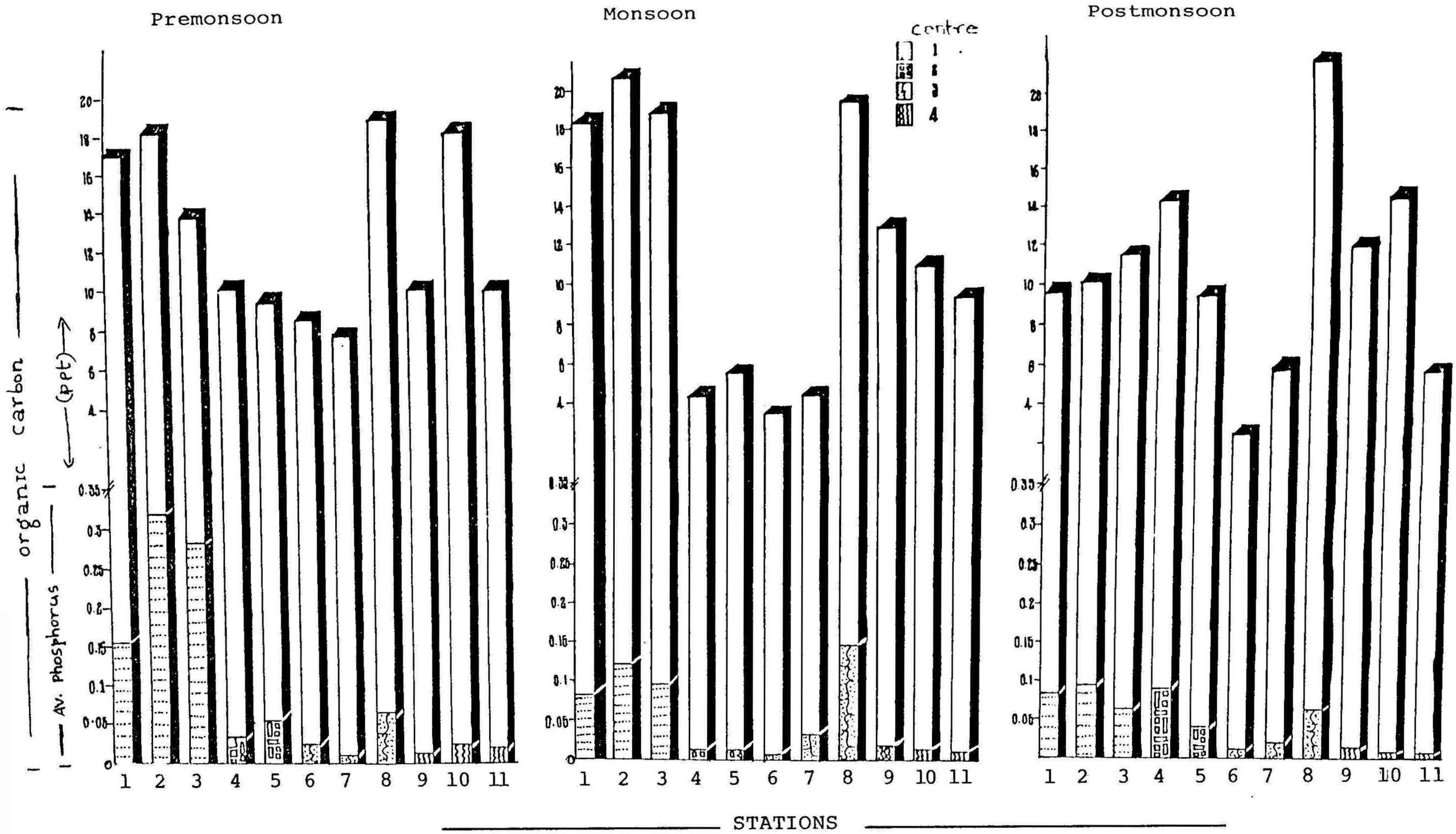


Fig. 12 Seasonal Variation of orgnic carbon and available phosphorus of soil in different stations

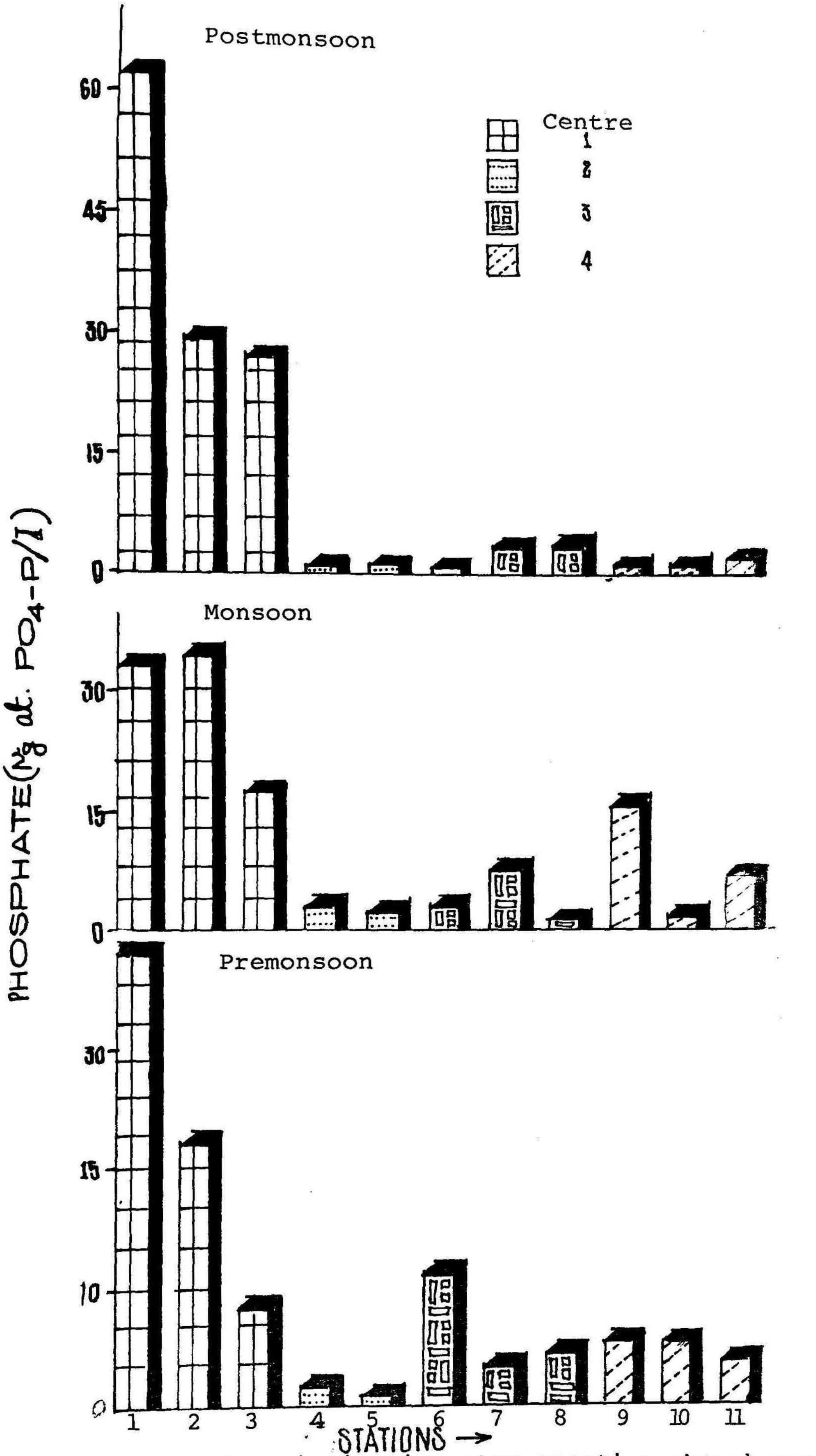


FIG: 13 Seasonal variation in water reactive phosphorus stationwise

Similarly organic carbon showed positive significant correlation with soil available phosphorus, available sulphur, alkalinity, TEC and clay content, 'r' being 0.38, 0.47, 0.296, 0.427 and 0.306 at $P<0.01$ respectively (Table 5). However, no significant correlation could be established between organic carbon and water silicate, soil pH, soil EC and soil nitrate etc.

Two way ANOVA reveals that there was no significant difference for organic carbon content of soil between centres . But significant variation at 1% level was observed between seasons. Similarly, interaction between seasons and centres showed significant difference at 1% level (Table 18).

Except in centre I, other centres showed a decrease in organic carbon during monsoon than that of premonsoon months. Though there was not much difference, the acid/hydromorphic saline soils recorded higher organic carbon content than that of alluvium soils with few exception.

Available sulphur

Available sulphur showed a wide fluctuation from 112.7 ppm at Puthuvypeen (station 8) during post monsoon to 4375 ppm at Vyttila (station 2) during premonsoon with an overall mean of 802.21 ± 364.9 ppm.

Correlation between soil available sulphur and soil EC (Table 5) was found to be positive and significant at 1% level,

Fig. 14 Soil Available Sulphur

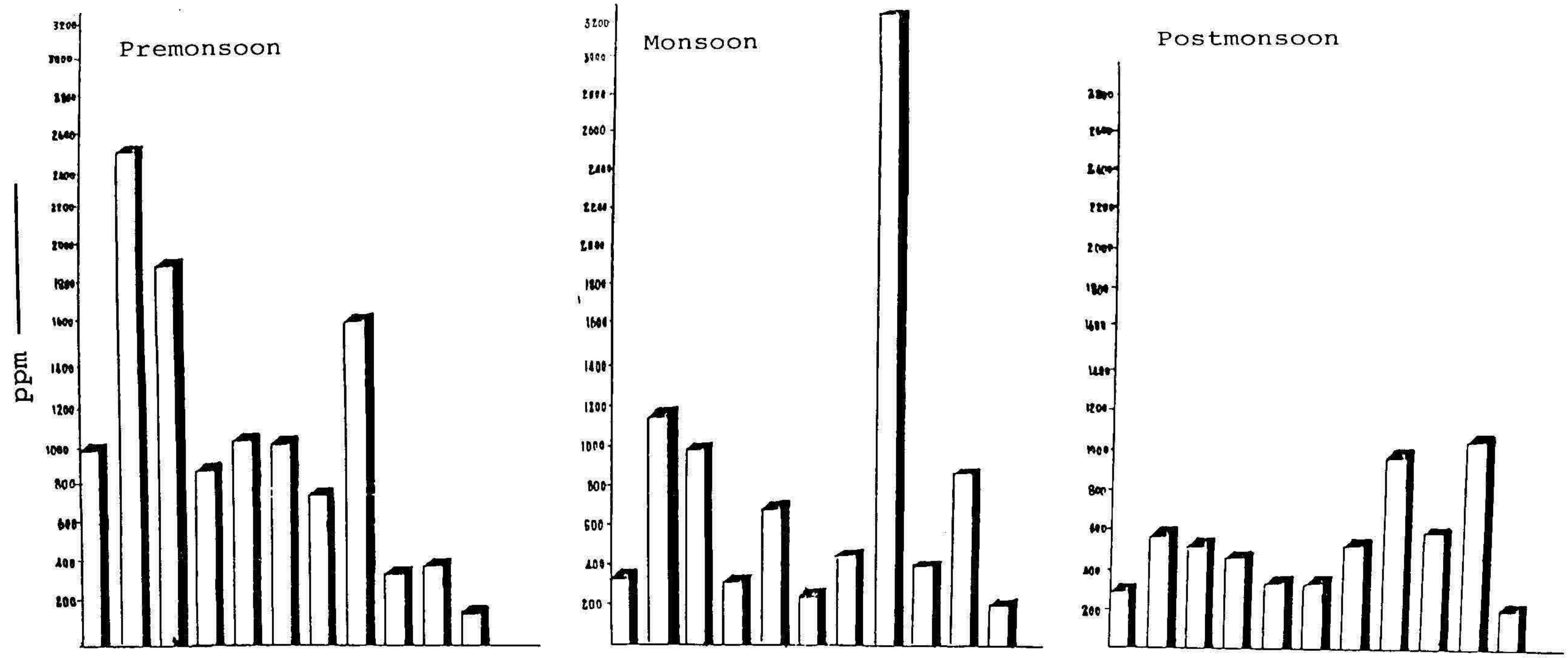


Fig. 15 Soil Nitrate

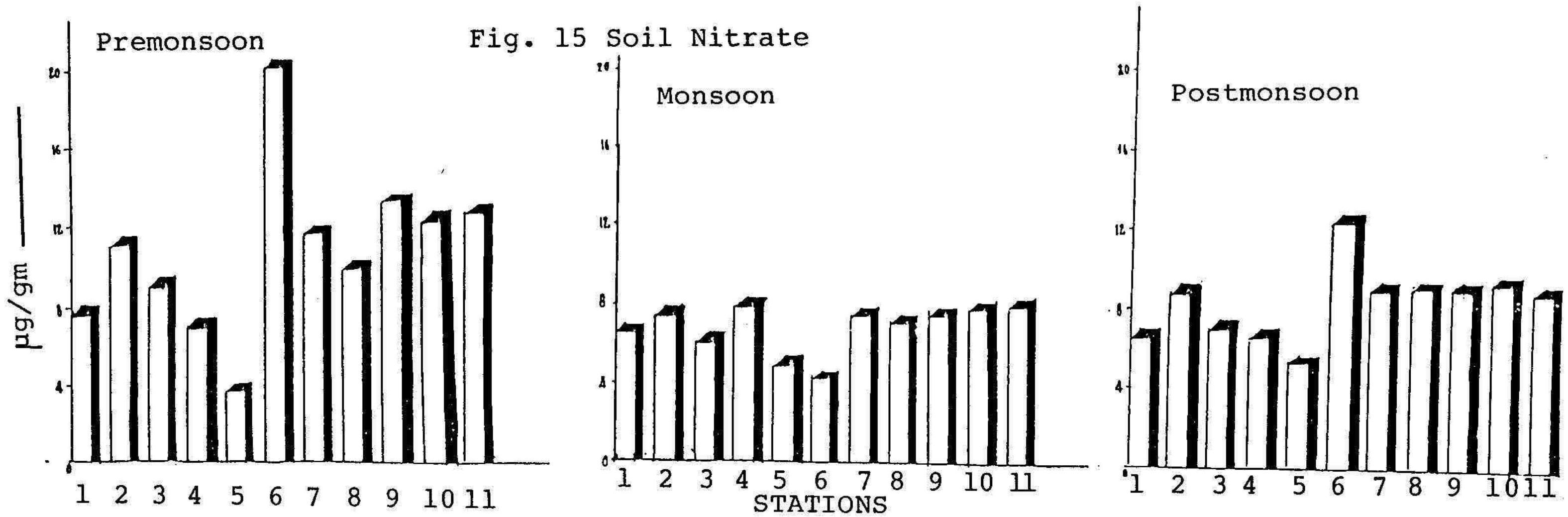


Fig. 14 Seasonal variation in soil available sulphur stationwise

Fig. 15 Seasonal variation in soil nitrate stationwise `r' being 0.469. Similarly soil sulphur showed positive correlation with soil organic carbon and also with soil TEC. No correlation could be established between soil available sulphur with water nitrate, silicate, soil pH alkalinity and pigments. However, with water phosphate there was a good correlation ($P<0.05$). Available sulphur showed a significant correlation with clay content of soil.

Two way ANOVA shows a significant variation in available sulphur content of soil from centre to centre at 5% level and among seasons at 1% level. From Table 2 it is evident that during premonsoon months the available sulphur was highest followed by monsoon and postmonsoon months. Among the centres , centre I showed highest available sulphur during premonsoon and monsoon months. However, during postmonsoon months the available sulphur was high in centre IV followed by centre III (Table 2 & 3).

Again there was variation in available sulphur content beteween the stations within a centre (Fig. 14). Seasonal variations, even at a particular station, were also observed.

Phosphorus

Reactive phosphorus of water showed wide fluctuation from 0.08 to 66 µg at/l with the lowest during postmonsoon months at Cherai (station 6) and the highest in the same season at Vennala (station 1) and with an overall mean of 13.85 $\pm$ 18.06 µg at/l. Soil available phosphorus was found to be between

4.48 to 414 µg/gm with lowest at Paravur (station 5) during monsoon and highest at Vyttila (station 2) in premonsoon and with an overall mean of 69.86 ± 84.70 µg/gm.

Correlation between soil and water phosphorus was found to be positive and significant at 1% level (r=0.574, 0.76, 0.54 and 0.506 for premonsoon, monsoon, postmonsoon and pooled data respectively). Water reactive phosphorus showed positive correlation with water nitrate, chlorophyll a and b and with soil available sulphur, but a significant negative correlation was observed between water phosphate and soil pH (Table 4). Correlation between soil phosphate with organic carbon and between soil phosphate with soil EC was found to be significant at 1% level. Between soil available phosphorus and clay also a significant correlation was observed ($P<0.01$) in the pooled data.

Two way ANOVA for water reactive phosphorus (Table 12) shows that significant variation at 1% level exist between seasons as well as between centres and also between the interactions. Similarly two way ANOVA for soil available phosphorus (Table 13) reveals that the values were differing significantly at 1% level between centres and also among seasons. However, interaction between seasons and centres are not differing significantly ($P>0.05$) as far as this parameter is concerned.

The average and standard deviation for each centre seasonwise is given in Table 2. The mean value of water phosphate and soil available phosphorus in each station seasonwise is shown in Fig. 13 & 12. Both water and soil phosphorus were higher in centre I in all seasons. Except for centre III all the other centres showed decrease in soil available phosphorus during monsoon than that of premonsoon months.

General decrease in water reactive phosphorus on the onset of monsoon was observed (Table 2 & 3). Among the centres , centre I showed the highest value whereas centre II recorded the lowest value, Similarly for soil available phosphorus, centre I and IV showed the highest and the lowest value in all seasons. Soil organic carbon and available phosphorus are shown in Fig.12 for each station seasonwise.

Nitrate - Nitrogen

Water nitrate varied from 0.31 µg at/l at Paravur (station 5) during monsoon to 74.3 µg at/l at Vyttila (station 2) during postmonsoon with an overall mean of 15.05 ± 18.36 in the pooled data. Soil available nitrate varied from 4.08 µg/gm at Paravur (station 5) during monsoon to 16.05 µg/gm at Vyttila (station 2) during post monsoon with an overall mean of 8.62 ± 6.48 µg/gm

The range and mean ± S.D. for these parameters are given in Table 2 & 3. The mean values of water and soil nitrate for

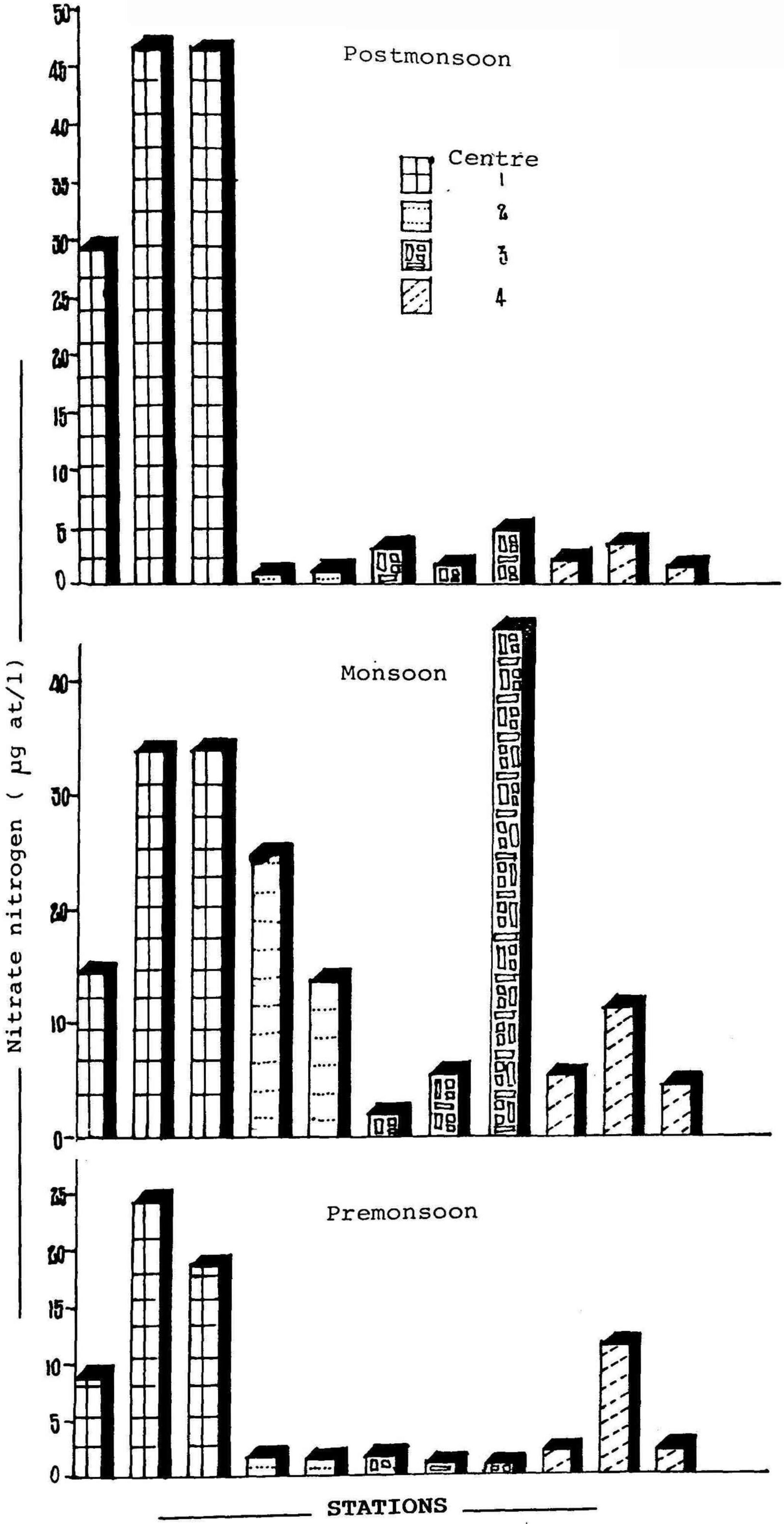


Fig. 16. Seasonal variation in water nitrate over the stations

each station seasonwise are shown in Fig. 15 & 16. No significant correlation was observed between soil and water nitrate. Correlation coefficients were found to be 0.136, 0.144, -0.087 for premonsoon, monsoon, postmonsoon and all seasons pooled together respectively.

Soil nitrate showed a poor correlation with all pigments as well as with nutrients of water. However, water nitrate content showed correlation with chlorophyll a, b and c, r being 0.269 ($P<0.01$), 0.234 ($P<0.05$) and 0.327 ($P<0.01$) respectively. Again, it showed significant negative correlation with water alkalinity ($r=-0.348$ at $P<0.01$), water salinity ($r=-0.335$ at $P<0.01$). However, with soil EC and soil sulphur it showed a very poor correlation (Table 5).

Soil nitrate neither showed any significant correlation with pigments and nutrients of water nor with soil organic carbon, available sulphur, available phosphorus etc.

Two way ANOVA (Table 14) reveals that there was significant variation in nitrate content of water from centre to centre and also in different seasons. Interaction between centres and seasons also showed significant variation within each other in water nitrate level.

Two way ANOVA (Table 15) also shows that there was significant variation in soil nitrate contents from centre to centre and among the seasons. Further, interaction between centres and seasons showed significant variation in soil nitrate content all at 1% level.

In all the stations there was a considerable increase in water nitrate during monsoon months. However, in postmonsoon months except for centre I these values decrease for all other centres (Table 2 & 3). Between the Centres, centre I showed highest water nitrate whereas centre II and IV showed lower levels of this parameter.

Soil nitrate showed a remarkable decrease in all the centres except for a mild increase in centre II during monsoon months. centre III showed highest soil nitrate content during premonsoon whereas centre II recorded a low value during same season (Table 3).

Nitrite - Nitrogen

Water nitrite varied between 0.02 and 7.0 µg at/l with the lowest at Vyttila (station 2) and the highest at Kundonoor (station 3) having an overall mean of 1.01 $\pm$ 0.876.

The range and mean $\pm$ S.D. for each centre seasonwise is given in Table 2 & 3. Nitrite showed a significant positive correlation with chlorophyll _a_ and chlorophyll _b_. Seasonal variation is observed with a decreasing trend during monsoon.

Water silicate

Silicate content of water showed fluctuations from 12.46 μg at/l at Karumady (station 10) during postmonsoon to 86.0 μg at/l at Paravur$_2$ (station 5), during monsoon with an overall mean of 47.16 ± 21.18 μg at/l.

The range and mean ± S.D. in each centre seasonwise is given in Table 2 & 3. Among centres, centre I showed high water silicate content followed by centre IV in the premonsoon and monsoon seasons. However, in centre II and III the silicate content was relatively less. Stationwise mean silicate content (Fig. 17) showed a marginal difference between stations of one centre. Increase in water silicate content was observed during monsoon months in all the centres. This trend was reversed in postmonsoon in all centres except for centre I (Table 3).

Silicate showed a highly significant negative correlation with water salinity ($r=-0.428$ at $P<0.01$) in pooled data, taking all ponds and all seasons together. Silicate also showed positive correlation with soil pH r being 0.298 significant at 1% level. Water silicate with water nitrate showed positive correlation having $r = 0.315$ significant at 1% level whereas silicate with photosynthetic pigments showed no good correlation. It did not show any correlation with soil clay, organic carbon, soil nitrate and available sulphur ($P>0.05$).

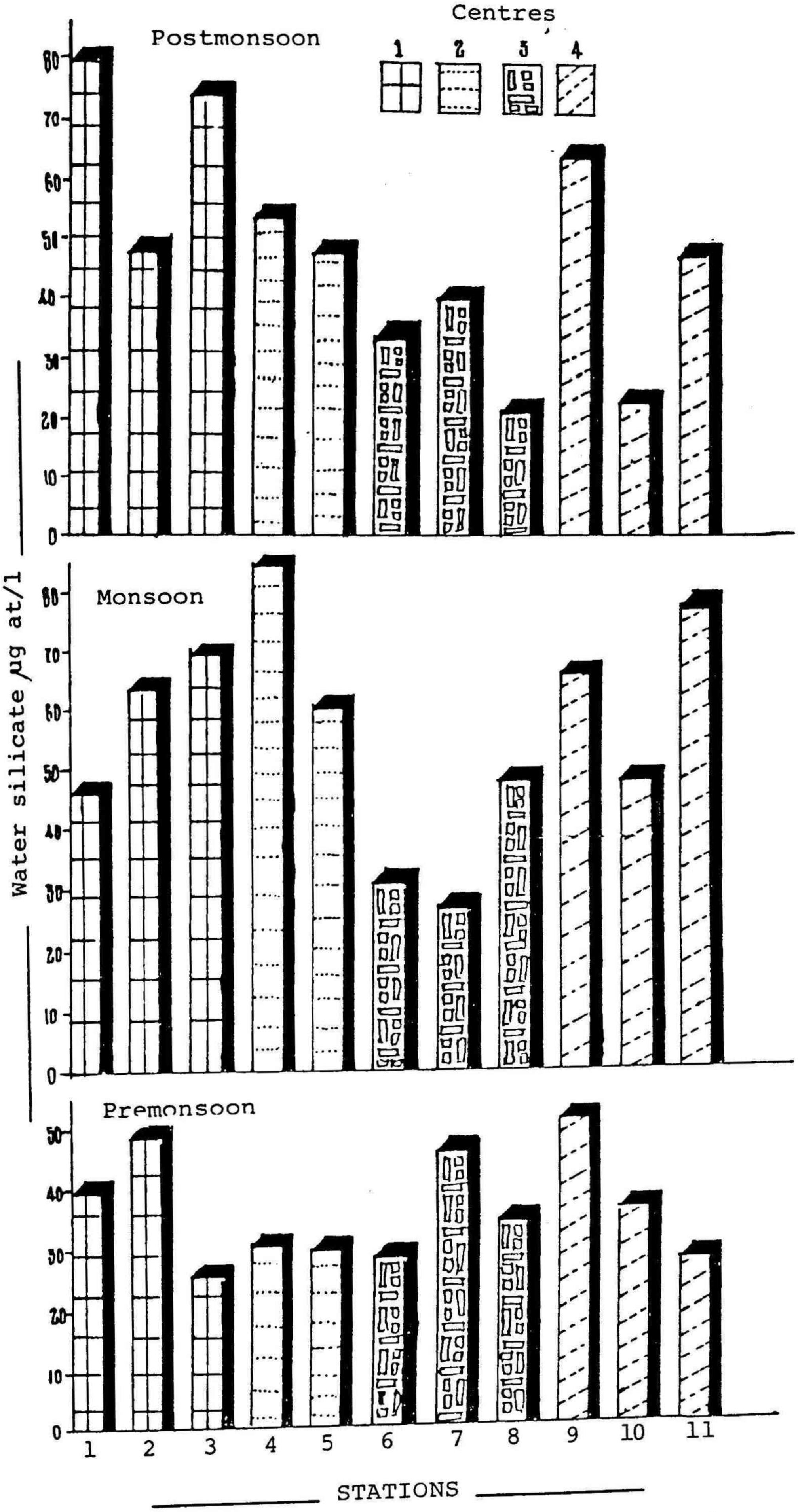


Fig. 17 Seasonal variation in water silicate stationwise

Two way ANOVA (Table 27) makes it clear that there was a significant variation in water silicate between centres at 5% level and among seasons at 1% level. Interaction between centres and seaons also showed significant variation of silicate at 1% level.

Photosynthetic pigments

In the present investigation, the most dominant pigment was chlorophyll a followed by chlorophyll c and chlorophyll b. Chlorophyll a the major index of standing crop of phytoplankton, was found to be as low as 1.93 mg/m^3 at Vennala (station 1) during premonsoon to as high as 116.84 mg/m^3 in Puthuvypeen (station 8) during premonsoon with an overall mean of 34.50 $\pm$ 21.93.

Chlorophyll b recorded the lowest value of 0.27 mg/m^3 at Vennala (station 1) during premonsoon to the highest 52.3 mg/m^3 at Puthuvypeen (station 8) during premonsoon with an overall mean of 16.52 $\pm$ 7.87 mg/m^3. Chlorophyll c ranged from 2.1 mg/m^3 at Vyttila during premonsoon to 126.6 mg/m^3 at Puthuvypeen (station 8) during monsoon with an overall mean of 20.85 $\pm$ 7.84 mg/m^3. Carotenoid pigment varied between 1.4 mg/m^3 at Cherai (station 6) during postmonsoon and 48.9 mg/m^3 at Puthuvypeen (station 8) during monsoon with an overall mean of 14.63 $\pm$ 5.94 mg/m^3.

With water nutrients like reactive phosphorus, water

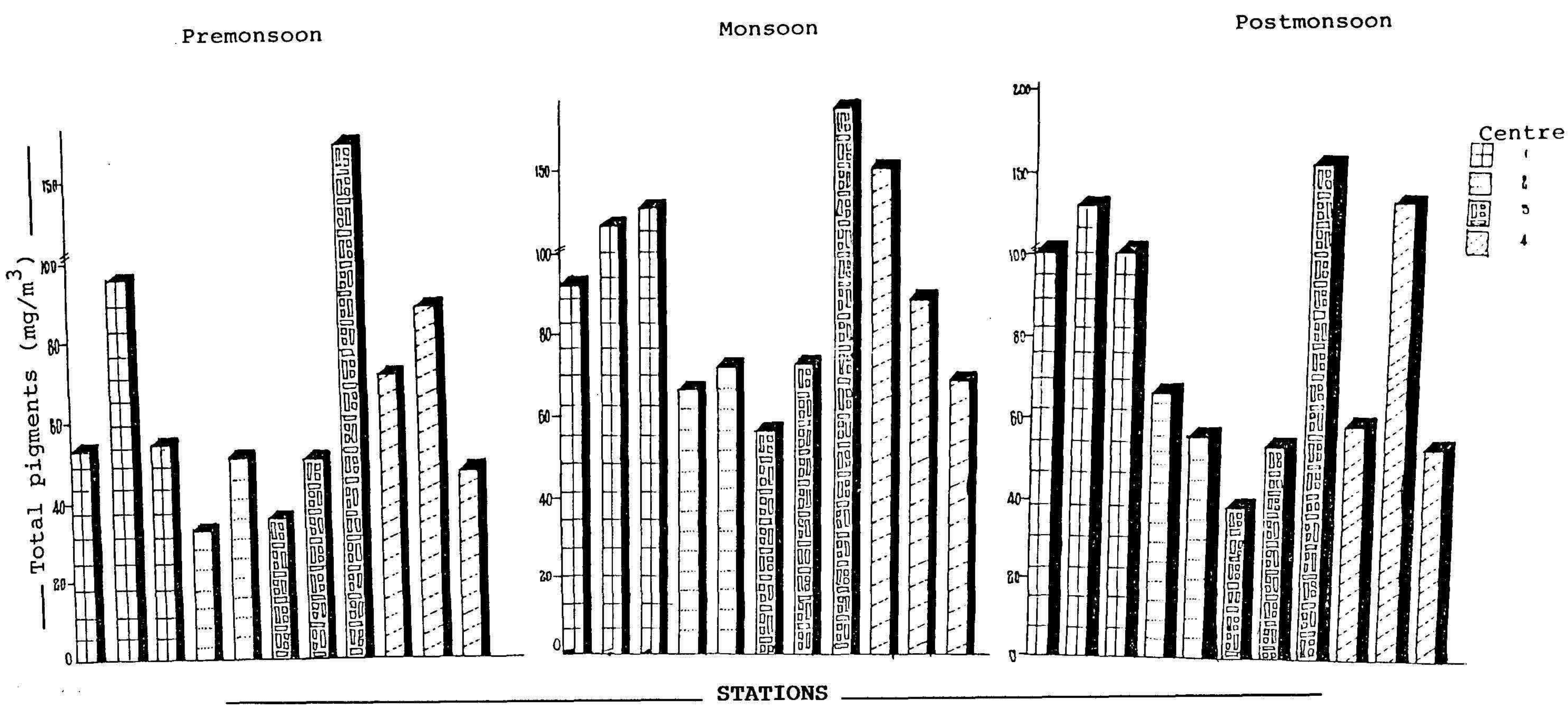


Fig. 18. Seasonal variation in total pigments in different stations

nitrate and water nitrite, chlorophyll a, b, c showed a more or less good correlation (Table 4). But no correlation was observed with water silicate. All pigments, chlorophyll a, b, c showed a positive correlation with soil organic carbon. However, they showed very poor correlation with soil available phosphorus and with soil nitrate.

Two way ANOVA (Table 23) shows that there was significant variation in chlorophyll a content of water between centres . However, seasonal differences were not observed with respect to this pigment. Likewise, no significant variation was observed between centres within a season or in a centre between seasons.

Two way ANOVA (Table 24 & 25) reveals that there was no significant variation of chlorophyll b and c between centres. However, there was a significant variation at 1% level between seasons. Again, interaction between centres and seasons shows variation at 5% level as far as chlorophyll b is concerned, but there was no variation with respect to chlorophyll c.

From Fig. 18 it is clear that every station showed variation in total pigment contents. However, in general, an increasing trend during monsoon months was observed in all the stations and this trend was maintained in the post monsoon months for all the pigments. The range and mean ± S.D. of these pigments as obtained in each centre seasonwise is given in Table 2 & 3.

Centre I was showing high chlorophyll a content in all the three seasons followed by centre III. Centre II & IV showed relatively less chlorophyll a content in premonsoon and postmonsoon months. Chlorophyll b was high at centre I in all the seasons whereas other centres showed more or less the same value with a meagre change with season. Chlorophyll c was higher in centre III followed by centre I and IV whereas centre II showed less value for this pigment.

Total pigment was high in Puthuvypeen station of centre III in all the seasons whereas at Paravur and Cherai stations the total pigments were less compared to other stations (Fig. 18).

Chlorophyll a showed a positive correlation with water alkalinity whereas other pigments did not. Soil exchangeable potassium showed significant correlation with all the pigments, chlorophyll a, b & c (r=0.409**, 0.411** and 0.208*). Between the pigments highly significant correlation was observed. Chlorophyll a/chlorophyll b, r=0.48**, chlorophyll a/chlorophyll c with r=0.38*, chlorophyll b/chlorophyll c with r=0.473**.

* Significant at 5% level
** Significant at 1% level

C/P & N/P ratio

In the present study C/P ratio in soil ranged between 48 to 864, the lowest being observed in centre I and the highest

Centre	Station	C/P ratio in Soil			NO_3/PO_4 ratio in Water		
		Premonsoon	Monsoon	Postmonsoon	Premonsoon	Monsoon	Postmonsoon
I	1	108	220	114	0.18	0.44	0.46
	2	57	168	109	0.73	0.98	1.59
	3	48	191	190	1.47	1.93	2.03
II	4	300	308	164	1.42	10.49	1.08
	5	164	436	230	1.74	7.38	1.53
III	6	331	558	216	0.18	2.50	11.74
	7	790	130	247	0.29	1.8	0.38
	8	289	131	338	0.51	7.28	0.94
IV	9	878	654	720	0.50	5.69	1.77
	10	768	582	864	1.50	0.79	2.93
	11	479	780	744	1.28	1.76	1.81

Table 7: C/P ratio in soil & NO_3/PO_4 ratio in water

values in centre IV with overall mean value of 373 $\pm$ 265. C/P ratio is generally increasing in all stations during monsoon.

Centre IV recorded highest C/P ratio followed by centre III and centre II whereas centre I recorded the lowest.

NO_3 : PO_4 ratio in water ranged between 0.18 and 11.74 with an overall mean of 2.33 $\pm$ 2.8. This ratio was marginally increased during monsoon in all stations except at station No.10. Centre II and III showed higher values whereas centre I & IV recorded lower value of this ratio. The C/P ratio in soil and NO_3 : PO_4 ratio in water is given in Table No. 7.

DISCUSSION

Morphological features

Properties	Centre I	Centre II	Centre III	Centre IV
Colour	Dark greyish brown	Light Grey	Stn. 7&8-Grey Stn. 9-dark-grey	dark brown to dark yellow brown
Consistency	Very sticky when wet, very firm when moisted & very hard when dried	Less sticky & Loose when moisted	Moderately sticky	Sticky when wet
Plasticity	Very plastic when wet	Less Plastic when wet.	Stn. 7&8 less Plastic Stn. 9 very Plastic when wet	Moderately plastic
Permeability	Slow permeability	High permeability	Moderate to High permeability	Slow permeability
Boundary	Clear smooth	Irregular	Irregular	Gradual Wavy
Texture (Heavy/Light)	Heavy	Light	Light	Moderately Heavy

Soil texture

Physically a mineral soil is a porous mixture of inorganic particles, decaying organic matter, air and water. Soil texture concerned with the size of the mineral particles and structure is the arrangement of soil particles into groups of aggregates. It is clear from the high correlation between these fractions of soil and nutrients as obtained in the present study that these property determine the nutrient supplying ability of soil. In the present investigation in most of the location, soil are found to be sandy loam, only one being sandy clay loam (Vyttila) and one clay loam (Puthuvypeen). Tang & Chen (1967) reported that ponds having sandy, loam to silty clay texture are fairly good in productivity from aquaculture point of view.

Nees (1946) reported that an ideal pond soil should not be too sandy to allow too much leaching of the nutrients, nor should it be too clayey to keep all the nutrients adsorbed in it. In the present study also sandy bottom ponds are showing less nutrient status. Analysis revealed that available nutrients of soil increases with decreasing grain size. Soil clay showed significant correlation with soil organic carbon, available phosphorus and exchangeable cations. Similar results are reported by many workers (Banerjea, 1967; Chattopadhyaya and Chakraborti, 1986).

It has been emphasized that most active portion of soil are in the colloidal state and that two distinct types of colloidal matter, inorganic and organic exist in intimate intermixture. The inorganic is present almost exclusively as clay mineral of various kinds and organic is represented by humus. Since the adsorption of nutrients, gases and attraction of particles for each other are all surface phenomenon, the significance of very high specific surface area of clay is responsible for the influence on nutrient dynamics as obtained in the present study. Brady (1980) reported similar findings and established the importance of clay (Fig. 32) in adsorption of various ions and nutrients. The textural classes obtained in the present study is in full agreement with NARP report which describes the soil types of Kerala.

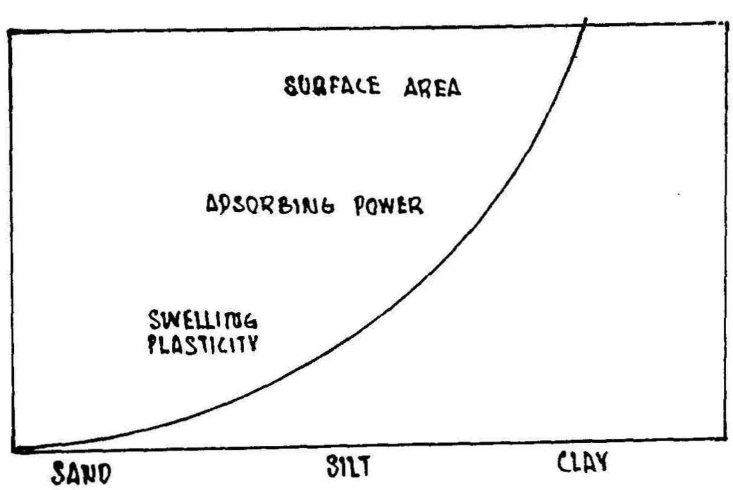


Fig. 32

According to Chattopadhyay (1978) the nature of clay minerals appeared to be the main factor for the presence of high amount of cations. The present study is in confirmity to this report.

Light And Temperature

Temperature is of course, no way a subject of interference while considering different types of soil since this parameter cannot be soil specific, though it influences the soil chemistry very much. The wide fluctuation in temperature is a phenomenon common to all these ponds studied. Temperature of water and soil generally depends on climate, sunlight and depth of pond, however have no direct adverse effect on the fish. But in ponds with high organic content in bottom mud, large scale mortality takes place in summer months in early morning when the surface water is suddenly cooled by a shower of rain or a cold wind. This happens due to the overturn of thermally stratified layers so that bottom layer of anaerobic decomposition zone, with reducing gases, distributes itself throughout the volume of water and relatively oxygen rich surface layer suffers oxygen depletion (Banerjea, 1967).

Temperature is an essential factor and influences the photosynthetic activity in water body, the biochemical and physiological activity of organisms stocked and the decomposition of organic matter in the pond bottom

Turbidity varies from pond to pond even in the same locality. While highly turbid water are undesirable for fish ponds, productive ponds are generally found to have slightly turbid waters. Secchidisc turbidity varied from 15 cm to 70 cm in the present study. Similar report are also shown by Sharly (1992) who mentioned secchidisc visibility to be of range 25 to 96 cm in these culture ponds. In the present study turbidity is positively correlated with chlorophylls.

Hydrogen Ion Concentration

pH is the measure of relative acidity or alkalinity and represents the negative logarithm of the concentration of free hydrogen ions in a solution. As far as soil pH (dry) is concerned in the present study 84-89% of ponds are found to be acidic while 11-16% are of neutral/alkaline in reaction. According to Ohle (1938) limit above or below of which pH has a harmful effect is 4.8 and 10.8. Nees (1946) remarked categorically that weak alkaline reaction (pH 7 to 8) has been found in most productive fish ponds and that very acid water are distinctly undesirable.

According to Alikunhi (1956) water of acidic soil are generally less productive than in alkaline soil. In the present study, considering the range of dry soil pH most of the pond located in hydromorphic saline and acid saline ponds are highly acidic in reaction (Dry soil pH=3.5 - 5.5) whereas alluvial soils are moderately acidic to neutral (dry soil pH = 5.52 to 7). However, due to submergence pH value is stabilized at neutral point in all types of soil.

Table 9: PRODUCTIVITY STATUS OF CULTURE PONDS STUDIED, WITH RESPECT TO SELECTED PARAMETERS

WATER ALKALINITY

(April-May) Premonsoon months				(June-Sept) Monsoon months				(October-November) Postmonsoon Amounts			
low	low to med.	Med-High	High productivity	low	low to med.	Med-High	High productivity	low	low to med.	Med-High	High productivity
0	5 (14%)	28 (75%)	4 (11%)	3 (8%)	19 (51%)	15 (41%)	0	3 (8%)	8 (22%)	18 (48%)	8 (22%)

Moyle (1946) 0-20 mg/l low production
20-40mg/l low to medium
40-90mg/l medium to high
> 90 mg/l highly productive pond.

WATER REACTIVE PHOSPHORUS

low	Fair	Good	Very good	low	Fair	good	Very good	low	Fair	Good	Very good
29 (78%)	5 (14%)	3 (8%)	0	28 (76%)	7 (19%)	2 (5%)	0	27 (73%)	6 (16%)	4 (11%)	0

Moyle (1946) 0-20 mg at/l - low
20-50 mg at/l - fair
50-100 mg at/l - good
100-200 mg at/l - very good

SOIL AVAILABLE PHOSPHORUS

low	Average	Productive	low	Average	Productive	low	Average	Productive
18 (48%)	4 (11%)	15 (41%)	18 (48%)	7 (19%)	12 (33%)	17 (46%)	3 (8%)	17 (46%)

Banerjea (1967) < 30 ppm -- poor
30-60 ppm — average
> 60 ppm -- productive

SOIL ORGANIC CARBON

low	Average	Optimum	High	low	Average	Optimum	High	low	Average	Optimum	High
1 (3%)	24 (64%)	11 (30%)	1 (3%)	6 (16%)	18 (48%)	9 (25%)	4 (11%)	5 (14%)	22 (59%)	8 (22%)	2 (5%)

Banerjea (1967) 0.5 % - low
0.5-1.5% - average
1.5-2.5% - optimum
2.5% Highly productive

CALCIUM CONTENT

low	Medium	High	low	Medium	High	Low	Medium	High
2 (5%)	4 (11%)	31 (84%)	3 (8%)	14 (38%)	20 (54%)	4 (11%)	9 (24%)	24 (65%)

Tang and Chen (1967) < 700 ppm low
700-1200 ppm medium
> 1200 ppm high in calcium

POTASSIUM CONTENT

low	Medium	High	low	Medium	High	low	Medium	High
0	4 (11%)	33 (89%)	0	6 (16%)	31 (84%)	0	3 (8%)	34 (92%)

Ganguly (1982) 0-50 ppm - low
50-125 ppm - Medium
125ppm - high in potassium

SOIL p^H

low	Average	Good	low	Average	Good	low	Average	Good
0	22 (59%)	15 (41%)	1 (3%)	19 (51%)	17 (46%)	1 (3%)	8 (21%)	28 (76%)

Banerjea (1967) > 8.5 & < 5.5 - Low
5.5 - 6.5 - Average
7.5 - 8.5 - Average
6.5 - 7.5 - Good

Acid soils high in organic matter and reducible ions Fe and Mn attains a pH of 6.5 - 7.0 within two to three weeks of submergence (Mandal, 1980). Banerjea (1967) reported that almost neutral soil reaction (pH 6.5 - 7.5) of ponds is good for fish culture, while moderately acidic (pH 5.5 - 6.5) and moderately alkaline (pH 7.5 to 8.5) are likely to produce average yields of fish.

In the presesnt study, out of 37 ponds, 15 to 28 ponds were of good and 8 - 22 ponds were of average and 0 - 1 ponds were of low categories as far as the above classification of pH is concerned.

The pH of the soil and water being highly correlated implies that this property of soil have much influence on water quality. Soil pH was found to influence many other parameters like soil alkalinity, CEC, TEC and exchangeable cations which is evident from the present study (Table 5).

A negative correlation exist between soil pH and available phosphorus in all the seasons. Ohle (1938) found that by increasing the pH, nutrient such as phosphate adsorbed on ferric hydroxide were easily washed out. The present findings are in well support of this statement since a higher range of pH showed low available phosphorus in soil.

Similarly water pH was highly correlated with water salinity, alkalinity and water nutrients which was in turn influenced by the soil types.

An overall decrease of pH during Monsoon in all stations confirms the findings of Khalaf and MacDonald (1975) that rainfall produce an immediate decrease of pH of the pond. Again the runoff water over the bund soil which are acidic, reduce the pH during monsoon.

From the lab experiments also it is clear that soil pH has a direct influence on water and in turn on the quality and productivity of the ecosystem.

Redox Potential

The redox potential expresses the oxidising or reducing power of a solution. The redox potential in the present study ranged from + 228 mv to + 549 mv. Rajyalakshmi et al. (1988) reported a wider range of redox potential in brackishwater pond sediments of Chilka lagoon from -39 to +760 mv. The minimum value were recorded at 0300 hrs and maximum at 1500 hrs time. Since in the present study sampling was mainly from 0800 to 1200 such a wider range could not be obtained.

A positive value of redox potential indicate the oxidising condition of the soil. Since the redox potential is a measure of decomposition of organic matter, it is important in the release of nutrients from mud to water (Wrobel, 1967). Mortimer (1941) observed that in the mud/water experimental systems, as soon as oxidising microzone was completely reduced and the 0.2 isovolt rose into the water, large amounts of phosphate, silicate, ferrous iron and bases were liberated into the water. Hutchinson (1957) concluded that under anaerobic condition the compounds produced low or high redox potential are unable to pass through the oxidative microzone because of their tendency to precipitate.

Since all the pond sediments studied were in oxidising state, exchange and adsorption of phosphorus was more than that in the reduced sediments. This is reflected highly in the interaction between soil and water phosphorus which otherwise, may not be remarkable.

Among the centres the ponds situated in hydromorphic saline and acid saline soil (centre I and IV) were showing relatively more redox potential values compared to that of alluvial soil (centre II and III). This may be due to considerable draining in these culture ponds or may be due to the soil specific reactions.

The present finding is in contrast to the report of Remesan (1990) who obtained a negative redox potential in these brackishwater ponds.

Dissolved Oxygen

In brackishwater ponds temperature, salinity and photosynthetic activity generally governs the dissolved oxygen concentration. The range of dissolved oxygen observed in the present investigation is in agreement with many studies conducted in these areas (Sheeba, 1992; Joshi, 1990). It showed a distinct pattern of seasonal fluctuation in these culture fields. Joshi (1990) reported dissolved oxygen to fluctuate from as low as 2 ml/l to as high as 9 ml/l .

Local production, diffusion and advection, exchange of oxygen across the surface and biochemical utilization have been found to control dissolved oxygen in many areas and this has been early demonstrated by Richards (1957). Dissolved oxygen is a factor reported to be of influence on the survival of Penaeus monodon in culture ponds (Verghese et al.1982.). In the present study dissolved oxygen showed good correlation with the photosynthetic pigments. With the increase of salinity, dissolved oxygen was found to decrease. Some times due to weed infestations some ponds showed very low level of dissolved oxygen.

Salinity

Salinity range obtained in the present study and its drastic fluctuations are in agreement with various authors worked in these area viz. Gopinathan et al. (1982) and Joshi (1990).

Soil salinity is influenced by the water salinity and it is clear from very good correlation obtained between them in the present study. Salinity change was greatly reflected in total hardness and alkalinity of water. Also change in salinity is reflected in exchangeable cations. However, this property of water is negatively correlated with water nutrients like phosphate, nitrate and silicate. Again, phosphate is not that much influenced by salinity as that of nitrate or silicate in water.

In the present study centres IV being situated in the upper streams was not very saline as observed in other centres throughout the period of study. But, coastal alluvium soil (centre III) showed higher salinity values. It may be due to closure approach to sea.

However, considering all the parameters it can be commented that, the abrupt rise and fall of the salt concentration of soil and water prohibits the stabilisation of the ecosystem.

Total Hardness

Hardness is the total concentration of calcium and magnesium expressed as calcium carbonate. Hardness of water is influenced by the exchangeable cations of soil as it is clear from the high significant correlation obtained between them. Hardness decreased in monsoon may be due to the fall of salinity because of high precipitation. Ponds located in alluvial soils were showing higher hardness than that of the acid saline and hydromorphic saline soils of centre IV and I. The decrease of hardness during monsoon was also reported by Banerjea (1967) and Sheeba (1992).

Soil Conductivity

The specific conductivity of soil is its capacity to conduct electric current and it depends on the nature and concentration of ionised salts. The wide range of soil-EC obtained in the present study is in full agreement with the report of Chattopadhyay and Chakraborti (1986) who while comparing EC of fresh water and brackishwater culture ponds, gave a range of 2 to 8 mmho/cm.

Soil EC showed a highly significant correlation with water salinity. This explains the monsoon decrease in soil EC. The abrupt decrease of EC in monsoon is attributed to high rate of precipitation and subsequent flushing operation by farmers (Chattopadhyay & Mandal, 1983). More clay content of soil influence the soil EC favourably may be because clay can adhere higher ions which increases in turn the conductance. In the present study positive significant correlation between soil clay and EC emphasizes this point.

Paliwal (1972) has described decomposition of organic matter to be lower under high EC values. However, a poor correlation was observed between soil EC and organic carbon. Highly significant correlation of EC with cations also indicate that this property of the soil is important in influencing the exchange capacity of soils. Again, the composition as well as the cycle of the microorganisms might be greatly affected by the sudden change in electrical conductivity (Chakraborti ., et al. 1985).

Among the types of soil studied, the ponds located in the coastal alluvium soil are having highest EC values whereas acid saline soil (Centre IV) showed lowest EC value in all centres.

The specific conductance of most soils increases after submergence, attains a maximum and decline to a fairly stable value which varies with the soil types (Iyer, 1987). This is evident in the present study since the pond soil showed comparatively high EC values than the corresponding bund soil. Increase in conductance in flooded soils is due to the release of Fe^{++} and Mn^{++} from insoluble Fe^{++} and Mn^{+++} oxide/hydrates and also due to the accumulation of NH_3, HCO_3 and R-COOH and the dissolution of $CaCO_3$ by CO_2 and organic acids. An additional factor is displacement of ions especially cations from the soil colloids by exchange reaction

Chattopadhyay and Mandal (1986) while studying brackishwater soils of West Bengal reported a positive significant correlation between soil EC and soil pH. In the present study also a highly significant correlation is obtained between EC and pH of the soil.

Alkalinity

Total alkalinity or acid combining capacity of water body are important to assess the productivity status of a pond. Alkalinity of brackishwater ponds are generally caused by carbonate and bicarbonate of calcium and magnesium. However, in the present study bicarbonate alkalinity was found to dominate in most of the ponds both in soil and water phase with a meagre fraction of carbonate alkalinity only in the coastal alluvium soil of Narakkal and Puthuvypeen.

Sheeba (1992) reported alkalinity range of 10 mg/l as $CaCO_3$ to 130 mg/l as $CaCO_3$ in the brackishwater ponds of Kerala. The present finding is in well agreement with this report. Statistically signficant correlation between soil alkalinity and water alkalinity indicate that soil have a definite influence on water in the pond ecosystem as far as alkalinity is concerned. Seasonal trend observed in present study is similar to that reported by Joshi (1990). Total alkalinity was high during premonsoon, but decreased in monsoon. Alkalinity minimum during monsoon and maximum during premonsoon has been reported by Chakraborti et al. (1985). He gave the range of 114 to 172 ppm desirable for *Penaeus monodon* production.

Moyle (1946), from a study of large number of lakes and ponds in Minnesota, had given the range of total alkalinity as

0.0 - 20 ppm for low production

20 - 40 ppm for low to medium production

40 - 90 ppm for medium to high production

> 90 ppm for highly productive ponds.

In the present investigation following this classification out of 37 ponds studied, 0-8 were highly productive, 15-28 were medium to high range and 5-19 were low to medium and 0-3 were of low productivity taking all seasons into account.

Ponds in coastal alluvium soil showed an average high alkalinity especially at Puthuvypeen which is exceptionally high in alkalinity of both soil and water. Soil pH is showing a significant correlation with soil alkalinity. This may be the reason for comparative low alkalinity in acid saline and hydromorphic saline soils compared to that of alluvium soil, as obtained in the present study.

CEC

The cation exchange capacity of these brackishwater culture ponds are least studied. In the present study, range of CEC obtained was 6 to 28 me/100 gm. Gopalswamy (1970) reported a range of 19 to 36 me/100 gm of CEC while dealing with coastal marshy soils. Boyd (1970) found that muds from Albama ponds had CEC ranging from 6.4 to 26 me/100 gm. Ghosh (1975) reported a value of 13.47 me/100 gm in the brackishwater ponds of Kakdwip. The present findings are in well agreement with these previous reports.

Exchangeable cations are available to planktons and micro-organisms. By cation exchange, hydrogen ion will replace nutrients from the exchange complex. In the present study no significant variation could be obtained between the stations. Among the stations, Puthyvypeen (station 8) recorded low CEC though higher levels of cations are observed in this station. Several factors like percentage base saturation of the nutrient cations concerned also will affect the CEC as well as nutrient release.

The negative correlation obtained between CEC and soil clay and soil pH, though not significant is doubtful. It cannot be justified under the scope of this study. However, Thompson (1961) reported that the CEC is partly pH dependent.

TEC

Total exchangeable metallic cations range as obtained in the present study is well in agreement with that of Gopalswamy and Raychoudhuri (1970). They reported these total exchangeable bases to be 19 to 36 me/100 gm for similar coastal marshy soils.

This property is also least influenced by change of season. All the stations also were similar in their TEC levels. Monsoon fluctuations may be influencing the nutrient mobilisation between water and soil phase. TEC showed significant correlation with soil pH, soil alkalinity and exchangeable cations. So there is lot of scope of this parameter to be defined and ventured with productivity rhythms.

Exchangeable K^+ Na^+ Ca^{++}

The soil fertility depends to a certain extent on the exchangeable cations present, nature of the soil, its structure and magnitude of its exchange capacity. Mollah et al. (1979) observed potassium contents of brackishwater pond soils in Bangladesh to be upto 640 ppm. Eswaraprasad (1982) reported potassium range 350 ppm to 1002 ppm and calcium from 6,739 ppm to 11,998 ppm. The range obtained in the present study is in accordance with these reports.

Exchangeable potassium showed good correlation with chlorophylls implying it's important role in maintenance of overlying water productivity. Pillay et al. (1962) also observed productivity of brackishwater ponds to depend largely on the form of exchangeable K^+.

The sharp decline of sodium and calcium contents of soils during monsoon periods in the present study might be due to relationship with salinity as opined by Eswaraprasad (1982). The increase in the amount of exchangeable Na^+ with the increase in the amount of water soluble Na^+ which in turn is salinity dependent, is established by the findings of Chattopadhyay and Mandal (1986).

Banerjea (1967) could not find any marked influence of calcium on productivity, however, reported that ponds can be grouped under four ranges of exchangeable Ca^{++} viz. < 100, 100-200, 200-300 and 300 mg/100 gm of soil. In the present study centre III showed highest Ca (3400.9 $\pm$ 2145.57 ppm) during premonsoon followed by centre II and I and lowest value was observed in centre-IV (665.87 $\pm$ 227.34 ppm) during postmonsoon. The algal pasture soils of Taiwan were classified by Tang and Chen (1967) based on their calcium content as low calcium (upto 700 ppm), medium calcium (700-1200 ppm) and high calcium (> 1200 ppm). In the present study, out of 37 ponds studied 2-4 ponds were low, 4-14 ponds medium and 20-31 ponds were high in calcium content (Table 9). The range of ponds given covers all the three seasons since calcium content in the same pond also varied with respect to season.

Most of the ponds in alluvial zone in the present study were high in calcium content compared to the acid saline soils. Dominance of Na^+, Ca^{++}, Mg^{++} in sea water (Harvey, 1960) and consequently in the estuarine waters, which serves as a source of water on backwater fish ponds might be the reason for the dominance of Ca, Na in these soils.

Sand fraction of soil showed significant inverse relationship with cations in all the sampling period. But silt and clay showed significant positive correlation with that of cations. Similar results were obtained by Mandal (1980). High EC value may be due to large amount of water soluble cations as evidenced from highly significant correlation between soil EC and exchangeable cations.

Organic Carbon

Organic carbon is most important factor determining fertility status of a soil. The range of organic carbon obtained in the present study is similar to that reported by Sheeba (1992). Positive correlation between fish production and organic carbon was reported by Banerjea (1967) while studying soil and water conditions of ninety fish ponds in acid saline and alluvium soils of different states. He reported that pond soils having less than 0.5% organic carbon are low in production and more than 2.5% are high in production. He mentioned that an average production could be obtained from ponds having 0.5-1.5 % organic carbon in its soil whereas ponds with 1.5-2.5 % organic carbon content could give optimum fish production.

In the present investigation, taking into account all the three seasons, out of 37 ponds studied, 1-6 were low, 18-22 average, 8-11 optimum and 1-4 ponds were high in production(Table 9).

Among the stations, Cherai and Puthuvypeen were low in productivity, ponds in hydromorphic saline (centre I) were of optimum to high productivity and acid saline (centre IV) were average to optimum whereas riverine and coastal alluvial soil were low to average/lower to high in their productivity. Soil organic carbon showed a positive correlation with percentage of clay and silt. Low values of organic carbon was found where sand content was more. This is also reported by Shanmukhappa (1987) while studying organic matter and C, N, P in sediments of Port Novo. Similar findings were also reported by Gopinathan et al. (1982).

Except for few cases a general decrease in organic carbon in monsoon was observed. It may be due to precipitation on one hand and decomposition of organic matter in peak summer on the other, as explained by Mollah et al. (1979). Detritus as a food of estuarine and nearshore organisms had been documented by various authors and normal abundance of detritus occurs in environment which have a high organic load (Shankaranarayanan & Qasim, 1969). Purandara & Dora (1982) reported the percentage of organic matter varies between 1.699 to 11.732 in and around Vembanad lake. However, in the present study it was found to be between 1.724 % and 5.17 % in the culture ponds.

Available Sulphur

Sulphur is known to be indispensable for many reactions in every living cells as a constituent of aminoacids, methionine and cystine, vitamines thiamine & biotin. It is not surprising that sulphur behaves much like nitrogen as it is absorbed by plants and microorganism and moves through the sulphur cycle (Brady, 1980). The present study showed available sulphur well within the range given by Sukumaran and Money (1967)for kari soils.

The range of available sulphur was high in acid sulphate soil of centre I whereas alluvial soil showed relatively less available sulphur. But in Puthuvypeen station where high content of clay was found, high sulphur values were obtained.

The wide range of available sulphur upto 4375 ppm at Vyttila is in agreement with that reported by Sundersan & Iyer (1987) who recorded range of 4205 ppm to 5015 ppm for the acid sulphate soils. He also reported high sulphur in premonsoon as obtained in the case of present study. Money and Sukumaran (1973) reported that Thiobacillus thiooxidans bacteria is observed in acid saline water logged soils of Kerala which use sulphur as a source of energy and sulphuric acid is formed as a result of their metabolism. Soil organic carbon on oxidation furnishes energy for sulphur reducing bacteria, sulphate ions serves as electron source for their respiration and thereby reduced to sulphide.

$$SO_4^{--} + 2CH_2O \longrightarrow H_2S + 2HCO_3$$

Amount of sulphate produced is directly related to the organic matter metabolised. Close relationship between them was reported by Harmsen (1954) and Berner (1970). In the present study also close relationship was observed between available sulphur and organic carbon of soil. Whenever there is a water-logged soil or sediment with a pyrite sulphur content greater than 0.5% the amount and distribution of carbonate determines whether or not an acid sulphate soil can develop. Supply of limited amount of dissolved oxygen appears to be necessary for pyrite formation. Overall pyrite formation with $Fe(OH)_3$ or Fe_2O_3 as a source of iron may be represented by

$$Fe_2O_3(S) \;+\; 4SO_4^{--}(aq) \;+\; 8CH_2O \;+\; \tfrac{1}{2}O_2(aq)$$

$$\longrightarrow 2FeS_2(S) + 11CO_3^{-}(aq) \;+\; 4H_2O$$

Kooistra (1978) suggested that sulphide oxidation at low tide may also generate acidity under this condition as carbonate are dissolved. In the present investigation alkalinity and pH of soil showing a negative correlation with available sulphur is supporting the view that in tropical estuarine sediments the conditions for in situ, Carbonate accumulation and high pyrite formation are mutually exclusive as reported by Iyer (1987).

In acid soils with high sulphur contents, drying of pond bottom produces severe acidity. Under these conditions the growth of algae and fish is very poor. From the lab. experiement the result showed similar findings as the growth of algae was inhibited in acidic condition.

Available sulphur showed a significant positive correlation with clay content of soil.

Phosphorus

The available phosphorus in brackishwater pond soil assumed comparatively higher values over fresh water ponds as reported by Chattopadhyay and Chakraborti (1986). The fact, that water and soil phosphorus were highly correlated in all the seasons, indicate influence of soil phosphate on that of water.

It is shown by Olsen (1964) that exchange of phosphorus is a very rapid process and that uptake of phosphorus from water by algae will be followed by a release from these sediments. In the oxidising state sediment exchanges and adsorbs more phosphorus than in the reduced state. Ohle (1938, 1964) has made some investigation on adsorption to humic acid and demonstrated a linkage of phosphorus and silicon to iron and aluminium humic acid complexes. In present study, the amount of phosphorus in Ca-p form may be higher in alluvium soil type of centre II and III whereas total amont of bound phosphorus as Al-P, Fe-P may be higher in hydromorphic saline and acid saline soil of Centre I and IV. Chattopadhyay and Mandal (1983) reported similarly while studying brackishwater ponds of West Bengal.

Moyle (1946) gave the water phosphorus fertility range as

	0 -	0.02	ppm	low
	0.02 -	0.05	ppm	fair
	0.05 -	0.1	ppm	good
and	0.1 -	0.2	ppm	very good in productivity

Out of 37 ponds studied, 2-4 ponds were good, 5-7 fair and 27-29 ponds were low in water phosphate content. In the present observation centre I showed good status whereas rest stations were low to fair in their phosphorus fertility.

Banerjea (1967) reported that available phosphorus of soil shows more regular correlation with pond productivity. Soil phosphorus level

< 30 ppm	Poor production
30 to 60 ppm	Average production
> 60 ppm	Productive

Accordingly most of the ponds in centre I showed high productive status whereas II and III are average and centre IV showed a poor productive status. However, Puthuvypen station of centre III showed high productive status. In the present investigation out of 37 ponds, 12-17 were productive, 3-7 average and 17-18 ponds were low in productivity.

In freshwater ponds the transformation of native phosphorus is mainly dependent on the reaction of pond soils, whereas in brackishwater ponds, in addition to such reaction water salinity also largely control the availability of phosphorus. It may be because of large amount of cations in brackishwater which form insoluble calcium phosphate compounds, thus decreasing the water soluble phosphorus. Sreenivasan (1967) found that those ponds having 500 kg/ha phosphorus are productive and those having more than 100 kg/ha are highly productive.

In the coastal alluvium soil (centre III), available phosphorus was increasing during monsoon. According to Chattopadhyay and Mandal (1983), the increase in quantity is due to lower fixation of phosphorus because of low Ca^{++} activity during monsoon.

A negative corelation was found between soil pH (wet) and available phosphorus of water. Macpherson et al. (1958) while experimenting on the equilibrium of phosphate with oxidised lake sediment, as a function of pH reported that in the pH range of 4.5-6.5 phosphate tend to be bound to solid phase by Fe^{3+} and Al^{3+} either by precipitation or by adsorption. Between the pH range of 7 to 9, very little phosphorus become adsorbed, but at high pH value tendency of phosphorus for precipitation is enhanced which appears to be related with the progressive decrease of solubility of calcium phosphate.

Nitrate - Nitrogen

The range and distribution of water nitrate and soil nitrate obtained in the present study is in well agreement with previous report by Pillai et al. (1975) and Sheeba (1992). Venkateswaralu (1969) observed no well marked relationship between nitrate nitrogen of water and that of soil. Mollah et al (1979) obtained an insignificant negative correlation between nitrate of soil and that of water. In the present investigation also no correlation was obtained between them. Vijayaraghavan (1973) reported an inverse relation between soil nitrogen and ammonical nitrogen of water.

In almost all the ponds studied nitrate of water showed increasing trend during monsoon. Shankaranarayanan & Qasim (1969) and Gopinathan et al. (1978) suggested that during the period backwater system remains predominantly marine, the nutrient concentration remains low and is homogenous throughout the water column but during the period of freshwater discharge (monsoon), high concentrations of nutrient occurs with gradient zone within the system. Water nitrate showed a general increase during monsoon in all the centres whereas soil nitrate showed a decreasing trend.

Soil nitrate was not correlated with organic carbon nor with soil EC, soil alkalinity, soil available sulphur and exchageable cations. This coincides with the view of Qasim et al. (1969) that while there is a close correlation between the cycle of phosphorus and organic production in Cochin backwater area, the nitrogen cycle is completely unconnected with producivity rhythms. For most part of the year there is little or no nitrate nitrogen in water. The chief source of nitrate in most ponds is from land drainage and runoff. However, Vijayaraghavan (1973) reported that productivity of a pond need not necessarily depend upon the total nitrogen content of soil. He obtained an inverse correlation between phosphate and nitrogen in soil.

Smith (1984) stated that biologist tends to favour nitrogen over phosphorus as the limiting factor, controlling productivity in the brackish/marine environment. The phosphorus load of water column is geochemically controlled at the sediment/water interface, but nitrogen on the other hand permeates biosphere in its molecular form and can be converted to reactive nitrogen by certain prokaryotes.

Water Silicate

Silicate content of water as obtained in the present study is in full agreement with Qasim et al. (1969) who reported that silicate in Cochin backwater fluctuate between 5.00 and 59.71 µg at./l in the surface waters and 4.79 to 35.73 µg at/l at 9 m depth layers.

Shankaranarayanan and Qasim (1969), Gopinathan et al. (1974, 1982) and Joshi (1990) observed high silicate values during monsoon season which coincides with the present finding. This high value recorded in monsoon may be due to the fact that the chief source of silicate is from soil, which in turn is brought down by land run off . The inverse correlation between silicate and salinity obtained in this study is in agreement with the findings of Shankaranarayanan and Qasim (1969). Sucevic & Dujmov (1988) opined that there was a net release of silica in the Dolland during late summer in the estuary. The origin of this silica may be dissolution of suspended material in the water phase.

Silicate dissolution in the water column takes place at a rate proportional to the rate of oxygen consumption by organic carbon and nitrogen. In the present study a high correlation between silicate and oxygen also support this view.

Photosynthetic Pigments

The chlorophyll carrying capacity of water column will be determined by the availability of limiting nutrients. Among the chlorophylls, chlorophyll a is the major pigment in the phytoplanktons which is able to transfer light energy into chemically bound energy whereas light energy absorbed by other pigments are also converted via chlorophyll a (Rabinowitch, 1951) However, in the present study distribution of total chlorophylls (a + b + c) is somewhat similar to chlorophyll a, being maximum during monsoon months. Chlorophyll values were more during monsoon almost in all stations followed by postmonsoon. Gopinathan et al. (1982) has reported chlorophyll values more during monsoon months, followed by postmonsoon months in his studies on phytoplankton in estuarine environment.

Chlorophyll c values were high and it's distribution was more during monsoon months like chlorophyll a. Qasim and Reddy (1967) have noticed high value of chlorophyll c in Cochin backwater during monsoon. However, chlorophyll b values were generally low in all centres during the period of study which is in confirmity with the work done by Bhargava and Dwivedi (1976)

All the pigments showed good correlation with soil organic carbon. This emphasizes the interaction between the euphotic zone and the shallow sediments. Pollenche (1986) reported that the concentration of organic matter, and it's fast turnover time are important in regulation of nutrients and hence on water productivity. Productivity in terms of pigments is showing good correlation with water nutrients which are more or less correlated with soil nutrients. In pond ecosystem, productivity is a function of nutrient supply which largely depends on sediment composition as well as variation in allochthonus contribution. However, beyond the critical concentration required for phytoplankton production excess nutrients may be just assimilated without further plant growth (Gerloff, 1969) which has been termed as 'luxury consumption' (Henderson *et al.* 1973) by the phytoplankton. In the present study phosphate and nitrate in soil which are also the index of productivity do not show any high proportionality with pigments. The ciritical concentration factor of the nutrients supply may probably be the reason for this.

Among the exchangeable cations potassium has higher holding on the productivity of water, since this parameter showed very good correlation with chlorophyll *a* and *b* and *c*.

C/P & N/P Ratio

In these culutre ponds C/P ratio was high as compared to the backwater systems. Shankaranarayanan and Parampunnayil (1979) reported C/P values of Cochin backwater in between 2.25 to 27.41. C/P ratio being the lowest in centre I indicated its high fertility status whereas in centre IV this ratio being very high showed its low fertility status. This may be because the conversion of organic matter into inorganic forms, which are instant and effective in 1st case whereas it is slow and ineffective in the later. Shanmukhappa (1987) reported that C/P ratio can be used as an index of domestic pollution in any aquatic body.

The water $NO_3 : PO_4$ ratio was found to be 0.18 to 11.74. Forsberg et. al. (1978) have suggested that an inorganic N/P ratio of less than 11 indicate limitation of nitrogen in phytoplankton biomass and between 11 and 27, both elements or another factor limits and for N/P ratio above 27, phosphorus is limiting. In the present study since the ratio was less than 11, it can be inferred that nitrogen was the limiting factor in these brackishwater culture ponds.

Stefenson and Richards (1962) suggested that anomalously low $NO_3 : PO_4$ ratios near the sea surface implies the N-regeneration and subsequent assimilation were too rapid to be observed in nitrogen concentration changes. The NO_3 : PO_4 ratic was almost constant with a slight increase during monsoon. This is supported by the observation of Pollenche (1986), that the phosphorus is mobilized more rapidly from decomposing organic matter than nitorgen. Further, denitrification process reduce the reactive nitrogen pool. Thus, P is enriched relative to N in the water column of these systems, providing a niche for nitorgen fixing organisms to convert excess Phosphorus to organic matter and hence restore the biological N:P ratio (Joshi, 1990).

From the foregoing discussion, it is evident that in culture ponds, the soil and water are in intimate interaction. This study enable us to highlight on the influence of different types of soil on water quality. However, since the observations were restricted to a short span of 8 moths covering few stations a definite conclusive inference in space and time could not be drawn.

LABORATORY EXPERIMENT

- OBSERVATIONS & DISCUSSION

Two way ANOVA for testing the variation between treatments (fertilizers; urea, ammonium sulphate and superphosphate), between soil types (alkaline, neutral, acidic) and between the periods of observation (Each 6 days interval) reveals the following important aspects.

ANOVA reveals that three tanks were differing significantly at 1% level as far as soil pH is concerned. Similarly three fertilizers were differing significantly at 1% level in influencing the gross production (Table - 30). There was significant difference at 5% level between the fertilizers with respect to cell counts of phytoplankton (Table - 33). Between the types of soil also significant variation at 1% level with respect to gross production, chlorophyll a (Table - 31) and total pigment contents (Table - 32) were noticed.

Between the periods of observation at 6 days interval there was significant variation in gross production, chlorophyll a and total pigments at 1% level and between the cell counts at 5% level. The gross production, cell counts and pigments were increasing from the 1st day onwards, reaching a peak level and then declining by the 36th day.

Critical difference analysis showed that there was significant variation between the response of each tank for

Two way Analysis of variance (ANOVA) tables showing the level of significance in variation of different parameters among tanks and over treatments. (Table 29-33).

Table 29: Soil pH

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Treatment	2	13.634	6.817	100.5298**
Tanks	2	197.048	98.524	1452.8956**
Interactions	4	5.689	1.422	20.9747**
Observations	6	5.186	0.864	12.7451**
Error	48	3.255	0.068	
Total	62	224.813		

Table: 30

Gross Production

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Treatments	2	0.430	0.215	6.2088**
Tanks	2	0.867	0.434	12.5214**
Interactions	4	0.366	0.092	2.6438*
Observations	6	1.361	0.227	6.5487**
Error	48	1.662	0.035	
Total	62	4.686		

Table: 31

Chlorophyil a

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Treatments	2	217.072	108.536	0.4685
Tanks	2	5121.102	2560.551	11.0538**
Interactions	4	809.896	202.474	0.8741
Observations	6	14297.819	2382.970	10.2872**
Error	48	11118.953	231.645	
Total	62	31564.843		

Table: 32

Total Pigments

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Treatments	2	1186.687	593.343	0.5463
Tanks	2	18922.993	9461.496	8.7110**
Interactions	4	377.954	94.488	0.0870
Observations	6	65210.392	10868.399	10.0063**
Error	48	52135.218	1086.150	
Total	62	137833.243		

Table 33 : Cellcount

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Treatments	2	1697280705079365	848640352539683	4.9336*
Tanks	2	368762325079365	184381162539683	1.0719*
Interactions	4	236483388253967	59120847063492	0.3437
Observations	6	2765186014285715	460864335714286	2.6792*
Error	48	825661069742855	172012722857143	
Total	62	13324323129841270		

* Significant at 5% level

** Significant at 1% level

different fertilizers and among tanks, for particular fertilizer. For all the three fertilizers higher average gross production was observed in neutral soil (tank-2) followed by alkaline soil (tank-1) while acidic soil (tank-3) showed least gross production.

Between the fertilizers, ammonium sulphate recorded higher gross production (mean 0.565 mgC/l/hr) for neutral soil (tank-2). But in alkaline and acidic soils (tank 1 & 3), superphosphate was found to induce higher gross production (mean 0.374 and 0.223 mg C/l/hr respectively), when compared to other fertilizers (Fig.30)

Similarly chloprophyll a and total pigment content showed higher values in neutral pH irrespective of the type of fertilizer used (Fig.21&22). Among the fertilizers ammonium sulphate was found to induce more chlorophyll a as well as pigments in neutral tank (mean being 49.016 mg/m^3 and 77.153 mg/m^3 respectively).

Critical difference analysis showed that there was no variation in chlorophyll a contents in the alkaline tank over all three fertilizers (Fig.31) and similarly for acidic tank also. No variation was found between superphosphate and urea in influencing the total pigments in alkaline and acidic tanks (Fig.22). However, total pigment production for superphosphate was found to be relatively better in both alkaline and acidic pH,

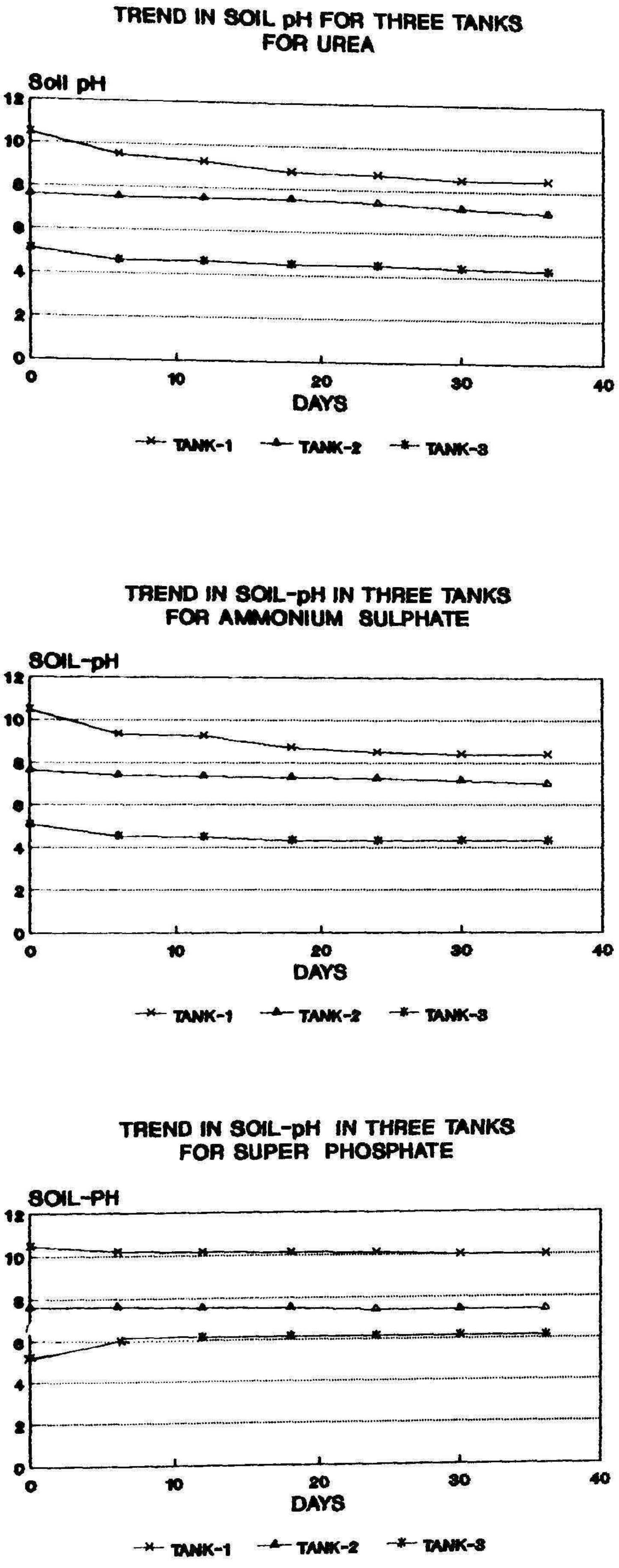
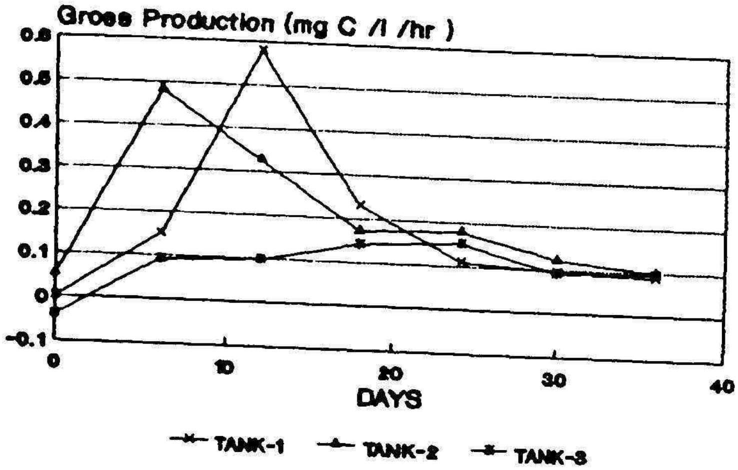
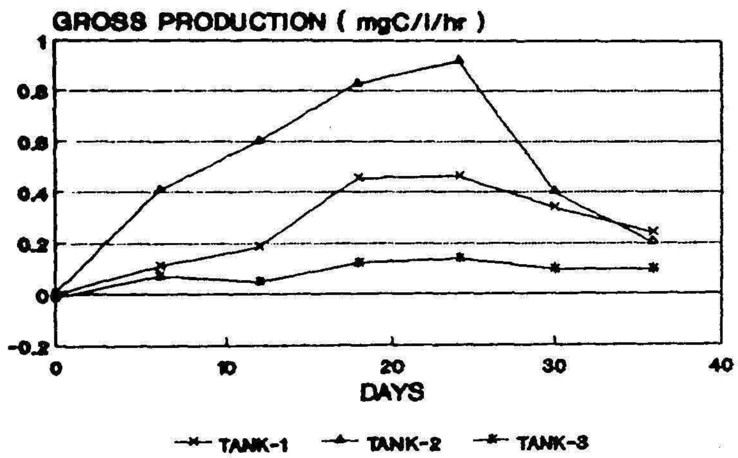

TREND IN SOIL pH FOR THREE TANKS
FOR UREA
Soil pH
12
10
8
6
4
2
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3
TREND IN SOIL-pH IN THREE TANKS
FOR AMMONIUM SULPHATE
SOIL-pH
12
10
8
6
4
2
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3
TREND IN SOIL-pH IN THREE TANKS
FOR SUPER PHOSPHATE
SOIL-PH
12
10
8
6
4
2
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3

FIG. 19

20a: TREND IN GROSS PRODUCTION FOR THREE TANKS FOR UREA



20b: TREND IN GROSS PRODUCTION IN THREE TANKS FOR AMMONIUM SULPHATE



20c: TREND IN GROSS PROODUCTION IN THREE TANKS FOR SUPER PHOSPHATE

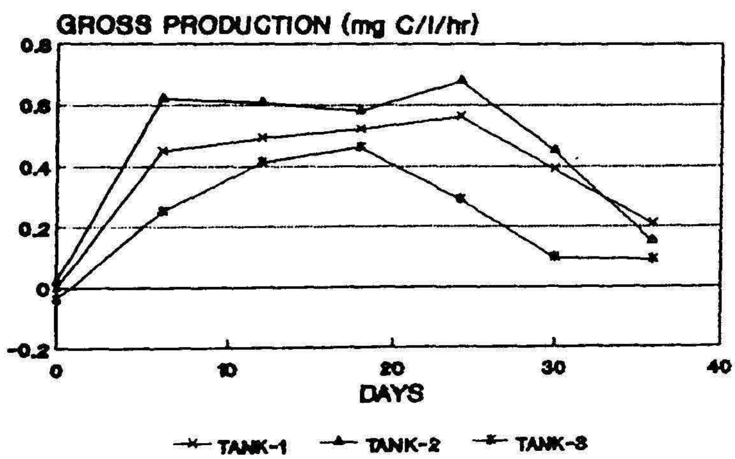


FIG. 20

PLATE V: Urea treated alkaline (Tank. 1) and Neutral (Tank. 2) systems

PLATE VI: Urea treated acidic system (Tank. 3)

PLATE VII : Photograph showing blooming in the culture pond

PLATE VIII: Bloom in neutral system (Tank.2) in contrast to acidic system (Tank.3) average being 75.347 mg/m^3 and 46.87 mg/m^3 respectively whereas for urea average was found to be 70.02 mg/m^3 and 36.6 mg/m^3 and for ammonium sulphate 65.75 and 29.43 mg/m^3 respectively. The observations at 6 days interval were differing significantly at 1% level in gross production, chlorophyll a, total pigments and in cell counts at 5% level.

Trend in Gross Production

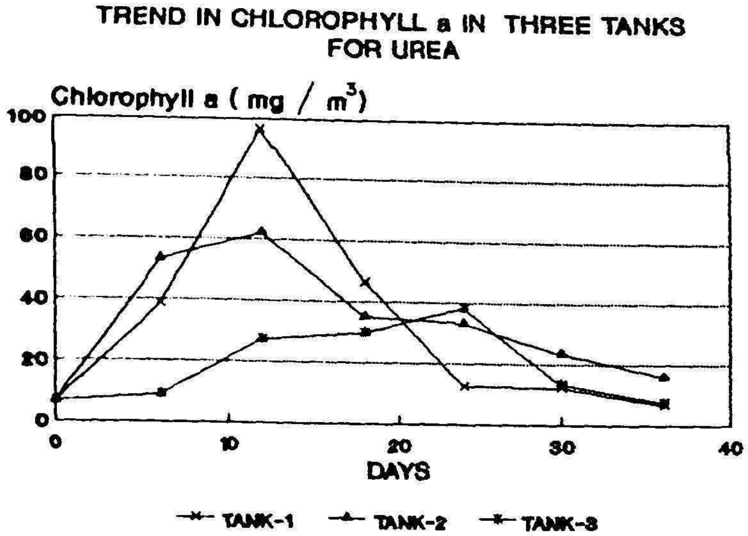
Trends in gross production with respect to subsequent observations at six days interval showed variation from tank to tank and between treatment to treatment (Fig.20).

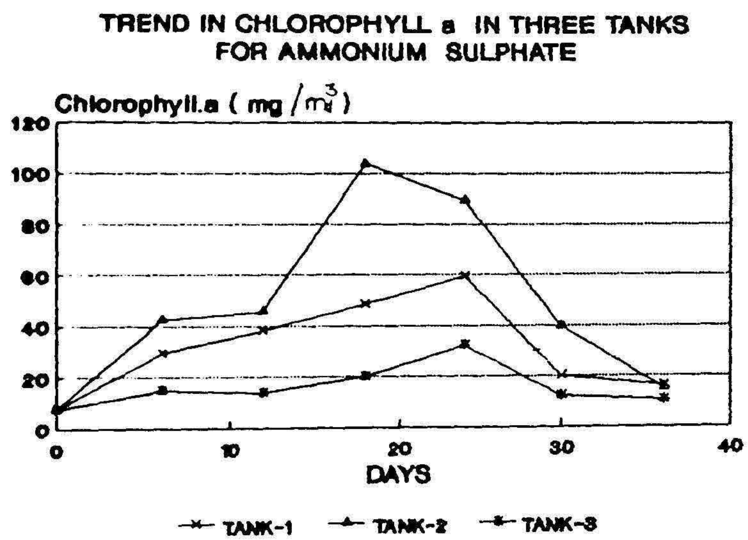
Urea (Treatment-1)

Gross production was increasing in alkaline tank upto the 12th day, reaching a level of 0.58 mgC/l/hr from and initial level of zero and then decreasing sharply by 24th day (0.11 mgC/l/hr). In neutral tank gross production attained maximum value by the 6th day (0.48 mgC/l/hr) and declined gradually till the 36th day and recorded a value of 0.123 mgC/l/hr. In the acidic tank, gross production increased upto the 24th day (0.152 mgC/l/hr) and then decreased by the 30th day upto 0.092 mgC/l/hr (Fig.20a)

Ammonium sulphate (Treatment-2):

In the alkaline tank gross production was increasing upto 24th day (from 0 to 0.463 mgC/l/hr) and then showed a decreasing trend upto 36th day (0.243 mgC/l/hr). In neutral tank, gross production was increasing upto 24th day (from 0.005 to 0.96 mgC/l/hr) and then decreased sharply to a level of 0.202 mgC/l/hr


TREND IN CHLOROPHYLL a IN THREE TANKS
FOR UREA
Chlorophyll a (mg / m3)
100
80
60
40
20
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3


TREND IN CHLOROPHYLL a IN THREE TANKS
FOR AMMONIUM SULPHATE
Chlorophyll.a (mg / m3)
120
100
80
60
40
20
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3

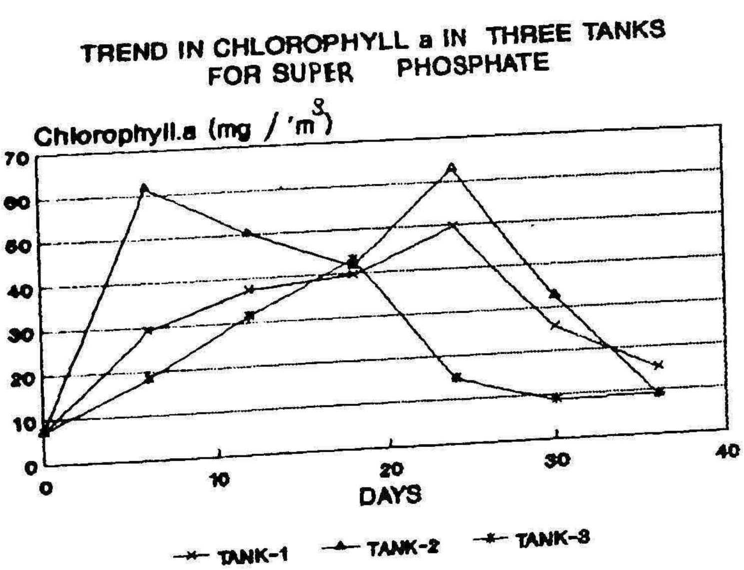

TREND IN CHLOROPHYLL a IN THREE TANKS
FOR SUPER PHOSPHATE
Chlorophyll.a (mg / m3)
70
60
50
40
30
20
10
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3

FIG. 21

on 36th day. For acidic tank there was no much variation in gross production except a mild increase upto 24th day (from an initial of -0.0014 to 0.14 mgC/l/hr) and again was decreased by 36th day upto 0.095 mgC/l/hr (Fig.20b).

Superphosphate (Treatment-3):

The results (Fig.20c) showed that in alkaline tank gross production was increasing upto 24th day (from zero to 0.56 mgC/l/hr) and then declined by 36th day (0.21 mgC/l/hr). In neutral tank gross production increased with little fluctuation till 24th day (from an initial value of -0.02 to 0.68 mgC/l/hr) following which it decreased by 36th day to 0.15 mgC/l/hr. In acidic tank gross production increased upto 18th day (from an initial value of -0.04 to 0.46 mgC/l/hr) and then decreased by 30th day (0.092 mgC/l/hr).

Trend in chlorophyll a

The chlorophyll a showed varied trends (Fig. 21) in subsequent observations in three tanks over application of three fertilizers. For alkaline tank highest chlorophyll of 96.4 mg/m^3 was observed on the 18th day from an intial value of 6.77 mg/m^3 for the application of urea but for neutral tank highest chlorophyll a of 103.9 mg/m^3 was observed on 18th day from an initial value of 7.23 mg/m^3 with ammonium sulphate application. For acidic tank, highest chlorophyll a was observed

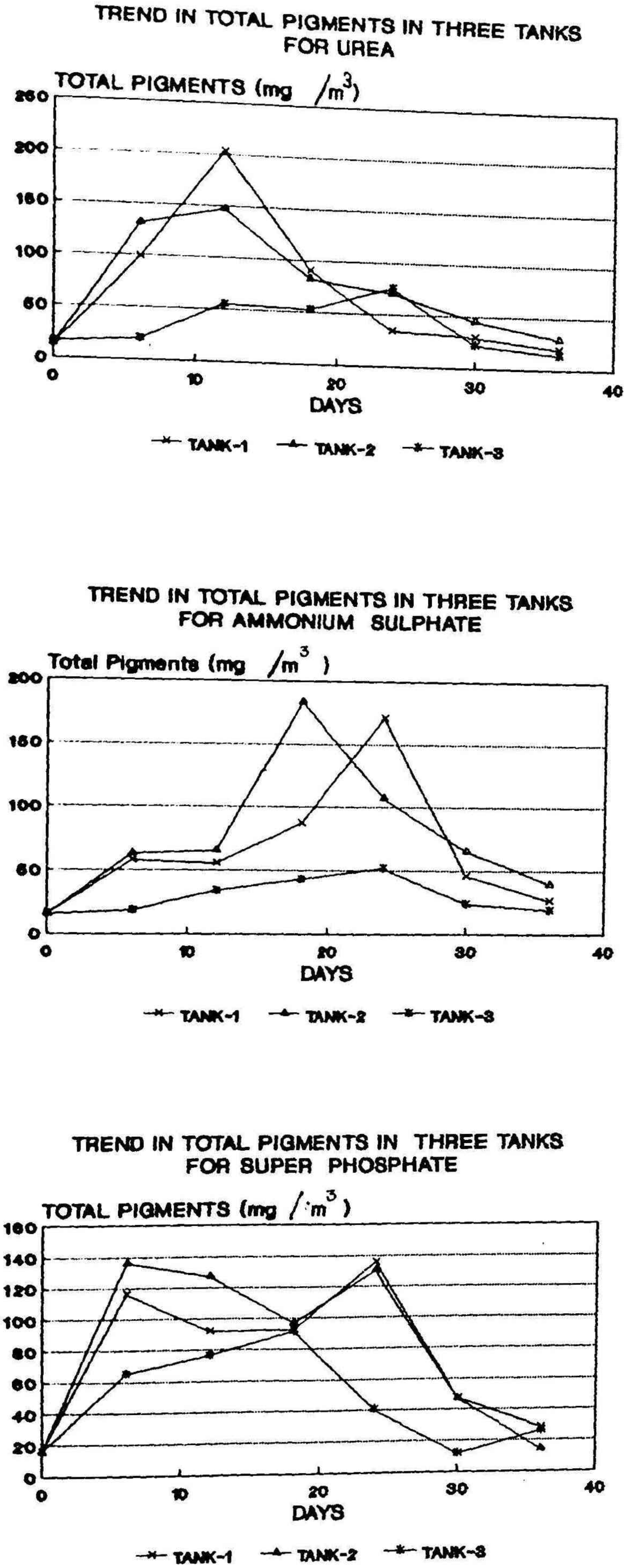

TREND IN TOTAL PIGMENTS IN THREE TANKS FOR UREA
TOTAL PIGMENTS (mg /m³)
250
200
150
100
50
0
0
10
20
30
40
DAYS
TANK-1 TANK-2 TANK-3
TREND IN TOTAL PIGMENTS IN THREE TANKS FOR AMMONIUM SULPHATE
Total Pigments (mg /m³)
200
150
100
50
0
0
10
20
30
40
DAYS
TANK-1 TANK-2 TANK-3
TREND IN TOTAL PIGMENTS IN THREE TANKS FOR SUPER PHOSPHATE
TOTAL PIGMENTS (mg /m³)
160
140
120
100
80
60
40
20
0
0
10
20
30
40
DAYS
TANK-1 TANK-2 TANK-3

FIG. 22

to be 43.07 mg/m^3 on 18th day from an initial value of 7.23 mg/m^3 with superphosphate application.

Trend in total pigments:

Total pigments (Fig.22) showed almost similar trends as those of chlorophyll a and gross production

Urea (Treatment 1):

In alkaline and neutral tanks an increasing trend upto 12th day was seen (202.98 mg/m^3 and 146.64 mg/m^3 from an initial value of 13.47 mg/m^3). In acidic tank slight increasing trend was observed upto the 24th day (from an initial 16.03 mg/mg^3 to 75.02 mg/m^3) following which, it declined.

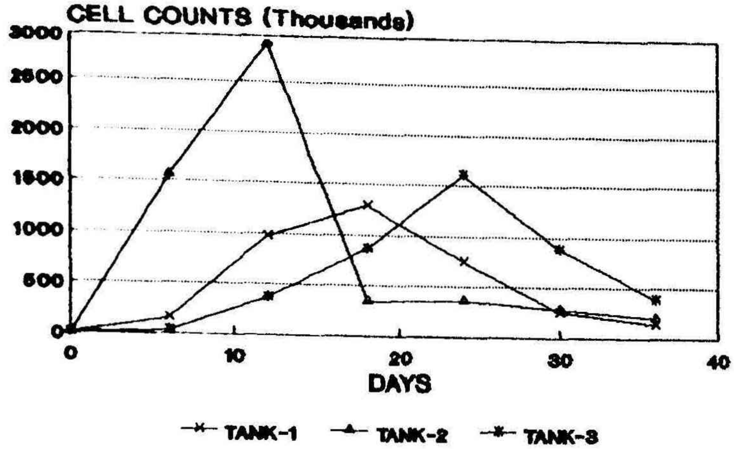
Ammonium sulphate (Treatment-2):

In alkaline tank and acidic tank total pigments increased upto the 24th day (171.21 mg/m^3 and 51.6 mg/m^3 respectively) from an initial level of 16.3 mg/m^3 after which it declined. In neutral tank peak was observed on the 18th day (183.63 mg/m^3) from an initial 6.03 mg/m^3, following which it declined to 39.23 mg/m^3 by the 36th day.

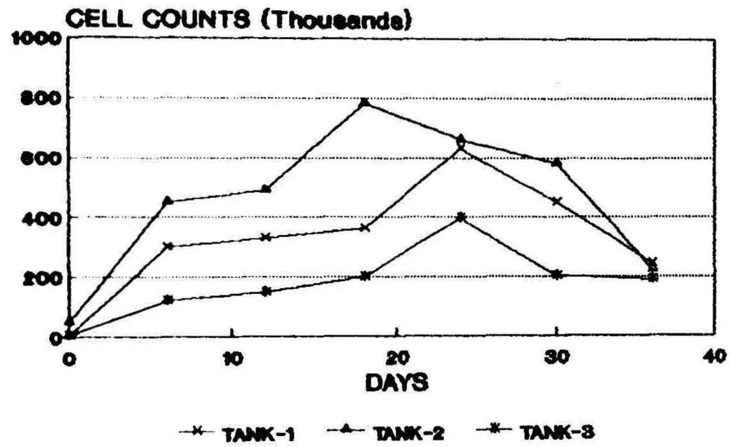
Superphosphate (Treatment-3):

In both alkaline and neutral tanks, the total pigments increased upto the 24th day (135.58 and 130 mg/m^3 respectively from an initial value of 16.03 mg/m^3), followed by a sudden

TREND IN CELL COUNTS FOR THREE TANK
FOR UREA



TREND IN CELL COUNTS FOR THREE TANK
FOR AMMONIUM SULPHATE



TREND IN CELL COUNTS IN THREE TANKS
FOR SUPER PHOSPHATE

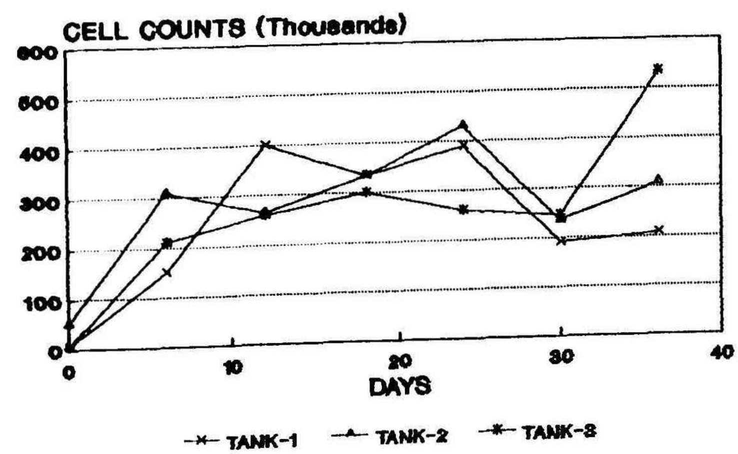


FIG. 23

decrease. However, in acidic tank highest total pigments was observed on the 18th day (91.76 mg/m^3) from an initial value of 16.03 mg/m^3, following which it declined upto 11.85 mg/m^3 by the 30th day.

Trend in cell counts

Trend in cell counts (Fig. 23) showed that neutral tank had a lead in both the 1st and the 2nd treatment (urea and ammonium sulphate), reaching upto $3x10^5$/ml and $0.8x10^5$/ml respectively from an initial count of 5000/ml and then declined. In superphosphate (treatment-3) application, both alkaline and neutral tanks behaved almost similarly. With few deviations, the acidic tank maintained a lower level of cell counts in all cases. In the peak phase of production, blooming of the respective tanks were noticed with Spirogyra sp., chlamydomonas sp. and other micro algae thus raising gross production to such a high level.

Trend in soil pH

The results (Fig. 19) showed that soil pH differs from tank to tank and from treatment to treatment, though initial pH was maintained almost same for a particular type of tank. In all the two nitrogenous fertilizers a decreasing trend was observed. In alkaline tank it decreased from 10.5 (initial) to 8.5 (36th day) for treatment 2 and 3. In neutral tank it decreased from 7.62 to 7.0 in 36 days of observations. In acidic tank, after an inital decrease, it remained almost constant (5.11 and 4.3 were the

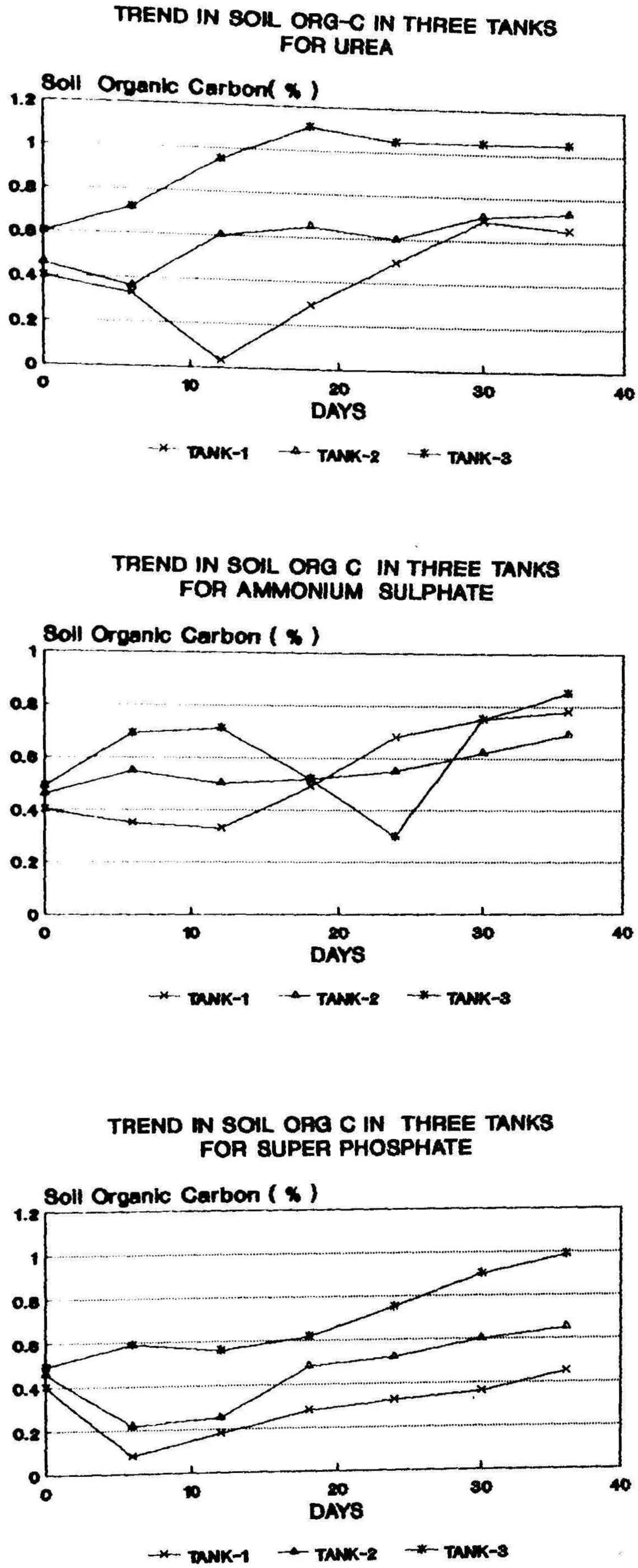
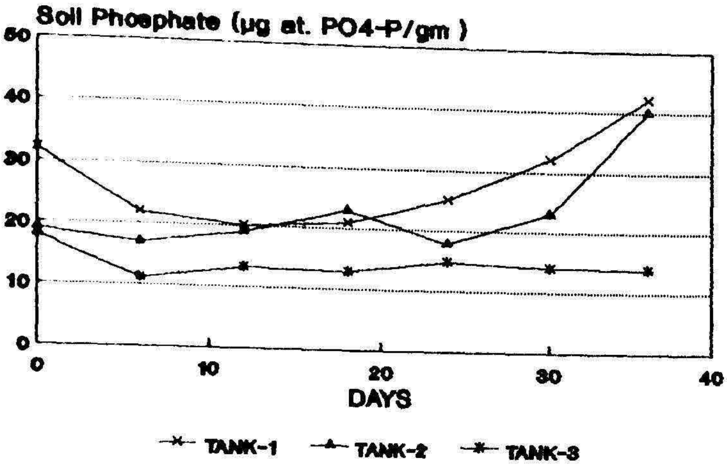
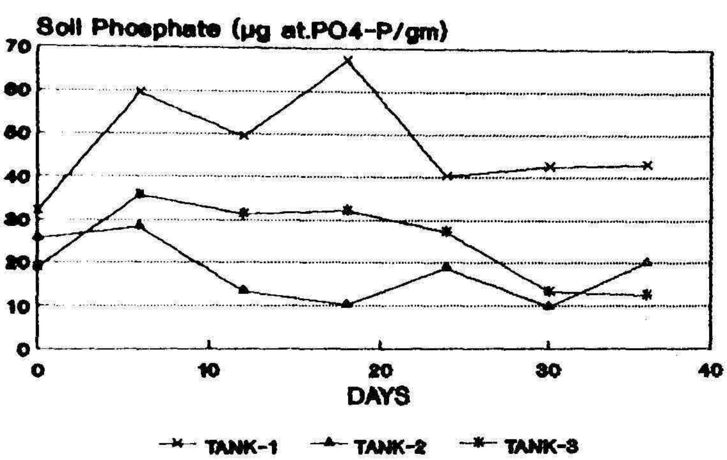

TREND IN SOIL ORG-C IN THREE TANKS
FOR UREA
Soil Organic Carbon(%)
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3
TREND IN SOIL ORG C IN THREE TANKS
FOR AMMONIUM SULPHATE
Soil Organic Carbon (%)
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3
TREND IN SOIL ORG C IN THREE TANKS
FOR SUPER PHOSPHATE
Soil Organic Carbon (%)
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3

FIG. 24

TREND IN SOIL-AV.PHOSPHATE IN THREE TANKS FOR UREA



TREND IN SOIL AV.PHOSPHATE IN THREE TANKS FOR AMMONIUM SULPHATE



TREND IN SOIL AV.PHOSPHATE IN THREE TANKS FOR SUPER PHOSPHATE

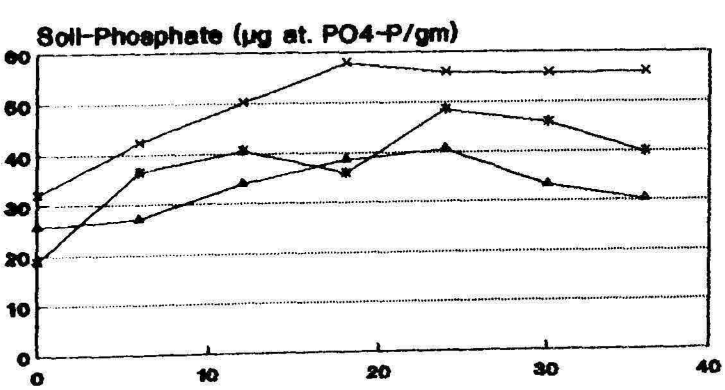
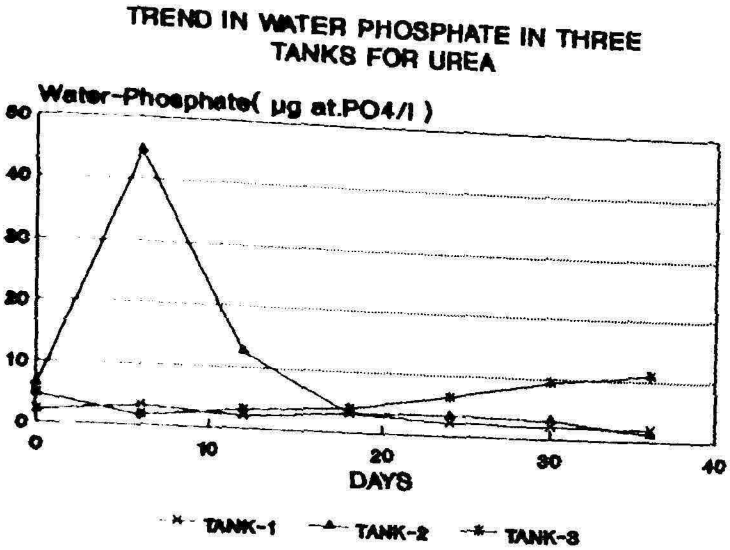
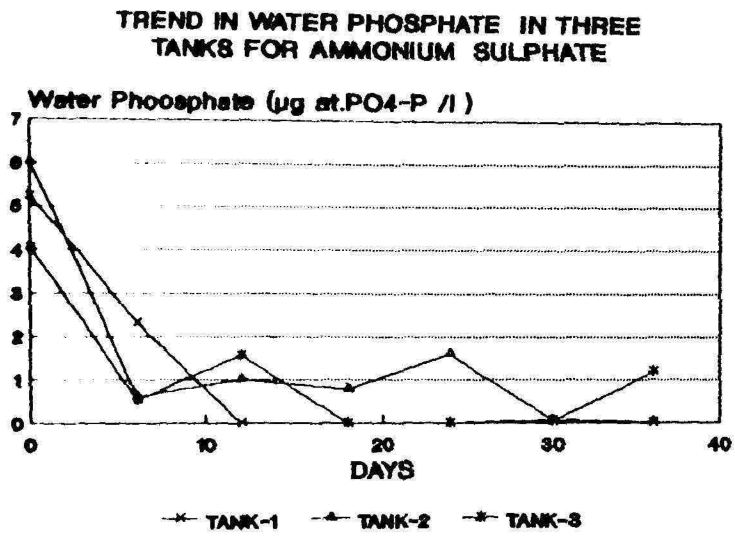


FIG. 25


TREND IN WATER PHOSPHATE IN THREE TANKS FOR UREA
Water-Phosphate(µg at.PO4/l)
50
40
30
20
10
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3


TREND IN WATER PHOSPHATE IN THREE TANKS FOR AMMONIUM SULPHATE
Water Phoosphate (µg at.PO4-P /l)
7
6
5
4
3
2
1
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3

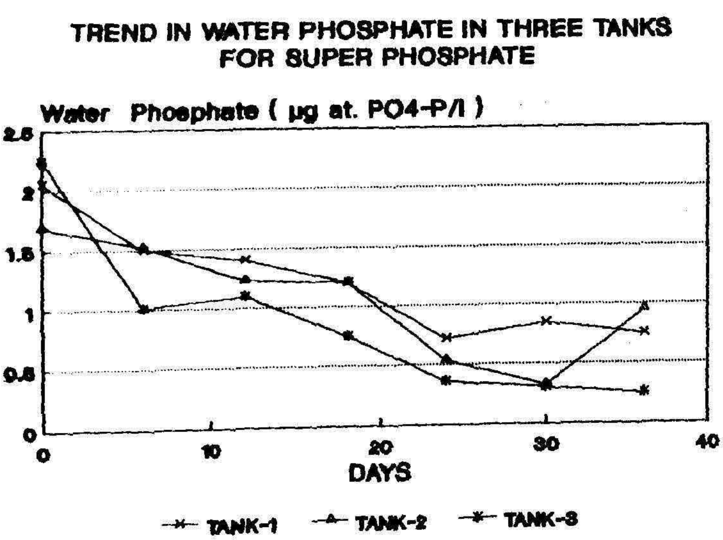
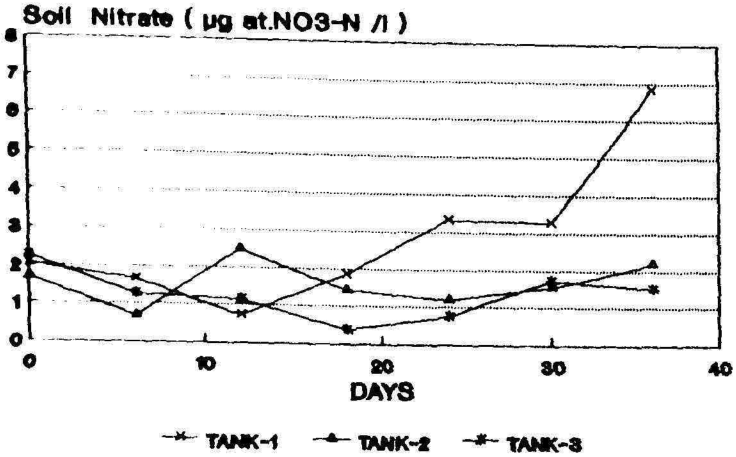
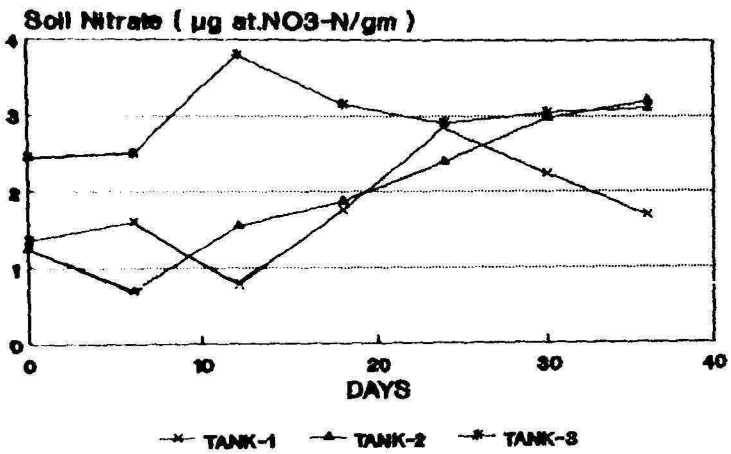

TREND IN WATER PHOSPHATE IN THREE TANKS FOR SUPER PHOSPHATE
Water Phosphate (µg at. PO4-P/l)
2.5
2
1.5
1
0.5
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3

FIG. 26

TREND IN SOIL NITRATE IN THREE TANKS
FOR UREA



TREND IN SOIL NITRATE IN THREE TANKS
FOR AMMONIUM SULPHATE



TREND IN SOIL NITRATE IN THREE TANKS
FOR SUPER PHOSPHATE

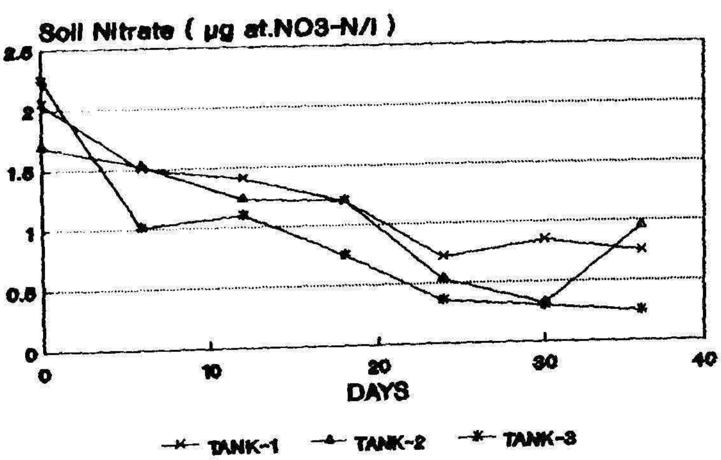


FIG. 27

initial and the final pH respectively). In the cases of treatment 3, pH decreased marginally from 10.5 to 10.0 in alkaline, 7.62 to 7.5 in neutral and increased from 5.11 to 6.15 in acidic tank.

Trend in Available soil phosphate

The results (Fig. 25) showed that among the tanks, alkaline tank showed high phosphate for all the three fertilizers followed by acidic tank and the least value was observed in the case of neutral tank in both, treatments 2 & 3, but in treatment 1 neutral tank showed high phosphate compared to acidic. Among the three fertilizers superphosphate also showed high soil phosphate value over an extended period.

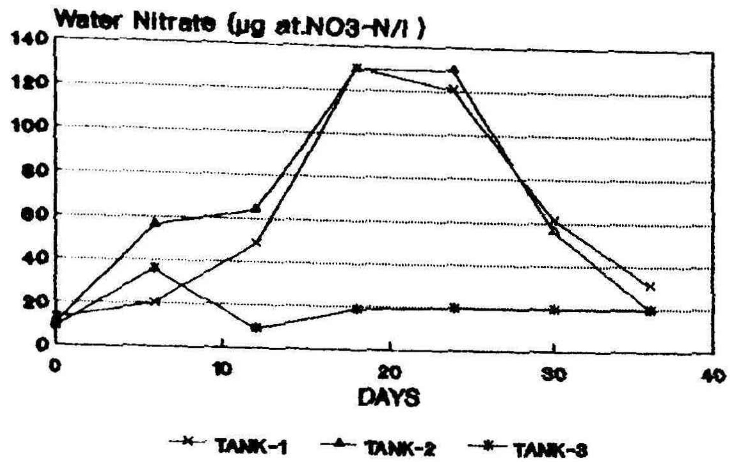
Trend in water reactive phosphorus

Water reactive phosphorus trend (Fig. 26) in alkaline and neutral tanks showed very low values even reaching traces in case of treatment 2. In case of treatment 1 also it showed a decline, but to a lesser extent. Acidic tank, however, showed lower water phosphate always. In case of treatment 3 (superphosphate), the reactive phosphorus initially increased in all the tanks to a very high value following which it declined gradually.

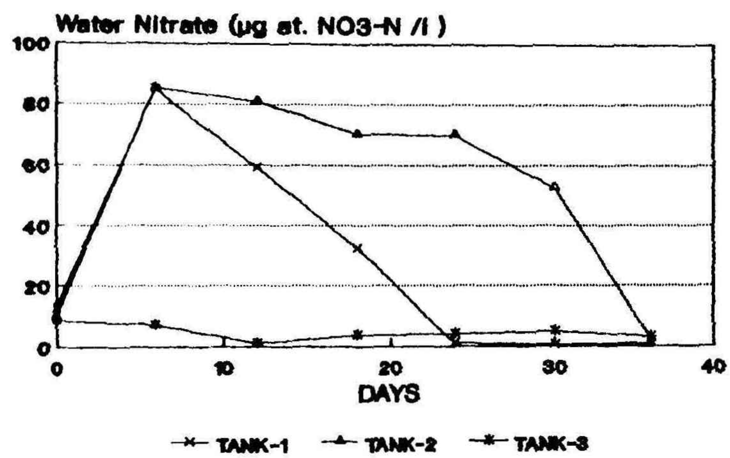
Trend in soil nitrate nitrogen

Soil nitrate nitrogen as given in Fig. 27, is relatively higher in case of urea as well as ammonium sulphate (treatment 1 & 2). In treatment 3, the nitrate nitrogen was decreasing as the days proceeded. Though acidic and alkaline tanks showed higher

TREND IN WATER NITRATE IN THREE TANKS
FOR UREA



TREND IN WATER NITRATE IN THREE TANKS
FOR AMMONIUM SULPHATE



TREND IN WATER NITRATE IN THREE TANKS
FOR SUPER PHOSPHATE

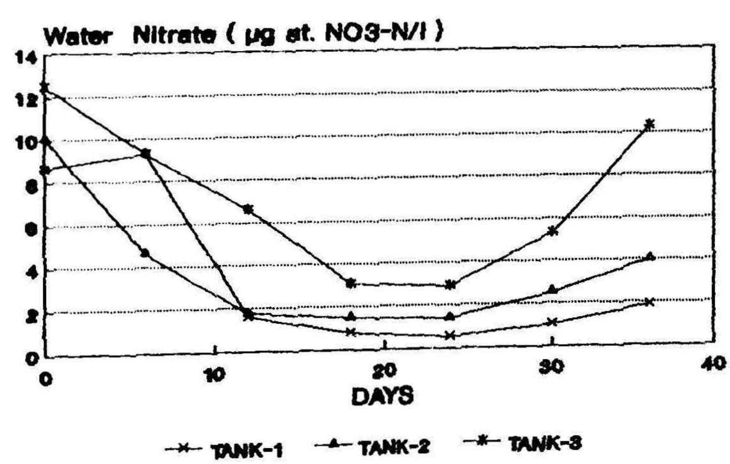


FIG. 28

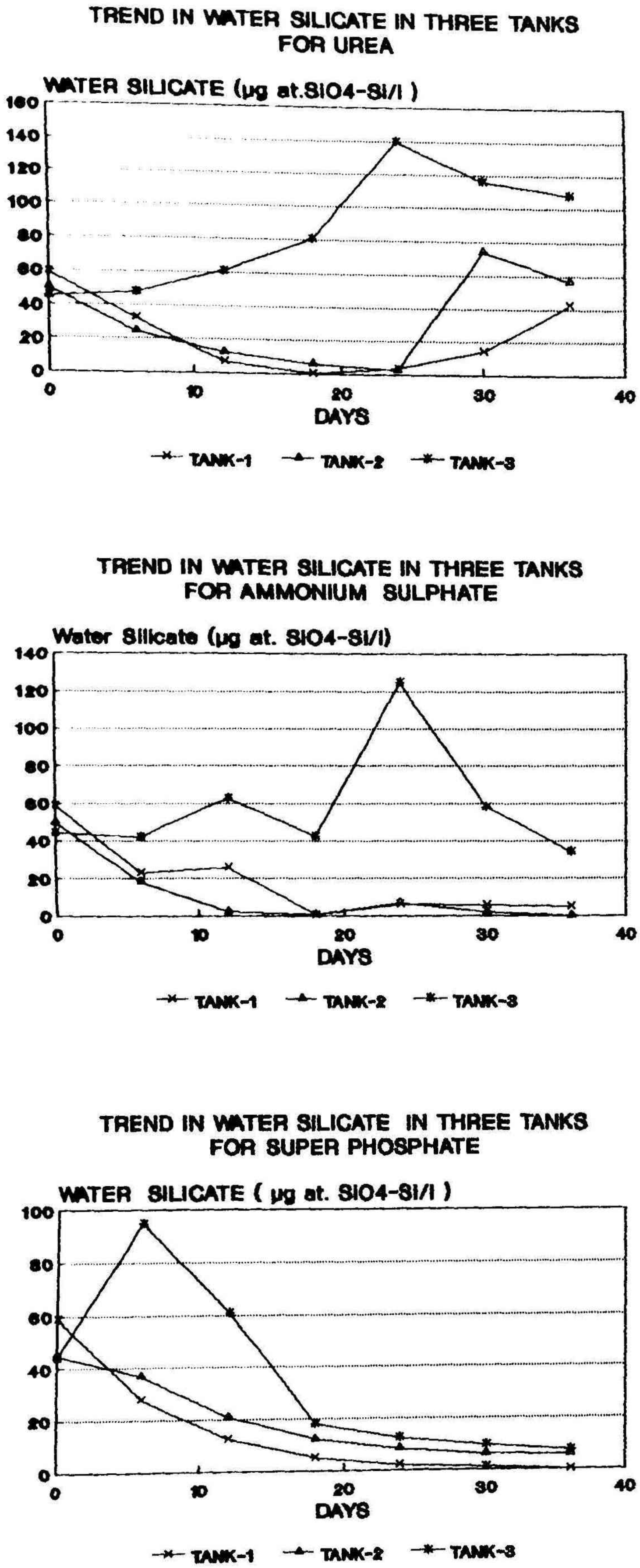

TREND IN WATER SILICATE IN THREE TANKS
FOR UREA
WATER SILICATE (µg at.SiO4-Si/l)
160
140
120
100
80
60
40
20
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3
TREND IN WATER SILICATE IN THREE TANKS
FOR AMMONIUM SULPHATE
Water Silicate (µg at. SiO4-Si/l)
140
120
100
80
60
40
20
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3
TREND IN WATER SILICATE IN THREE TANKS
FOR SUPER PHOSPHATE
WATER SILICATE (µg at. SiO4-Si/l)
100
80
60
40
20
0
0
10
20
30
40
DAYS
TANK-1
TANK-2
TANK-3

FIG. 29

nitrate nitrogen values than neutral tanks, no common trend as such was observed.

Trend in water nitrate nitrogen

For nitrate nitrogen in water (Fig. 28), the lowest value was observed in the case of superphosphate (treatment 3). Urea attributed higher water nitrate in both alkaline and neutral tanks. But in acidic tank water nitrate remained low, even after application of nitrogenous fertilizers. Ammonium sulphate suddenly increased the nitrate content whereas in case of urea the increase was very much gradual and the same way it declined.

Trend in water silicate

Water silicate as given in Fig. 29, was always higher in acidic tank irrespective of the treatments. However, blooming in the alkaline and neutral tanks determined the silicate content, which declined at the peak bloom. In case of treatment 1, silicate level increased after the bloom went down. In case of other two treatments silicate level went down to low levels in alkaline and acidic tanks also.

Trend in soil organic carbon

Soil organic carbon (Fig.24) showed that for all the treatments acidic tank maintained a high level of organic carbon followed by neutral tank while alkaline tank showed the lowest

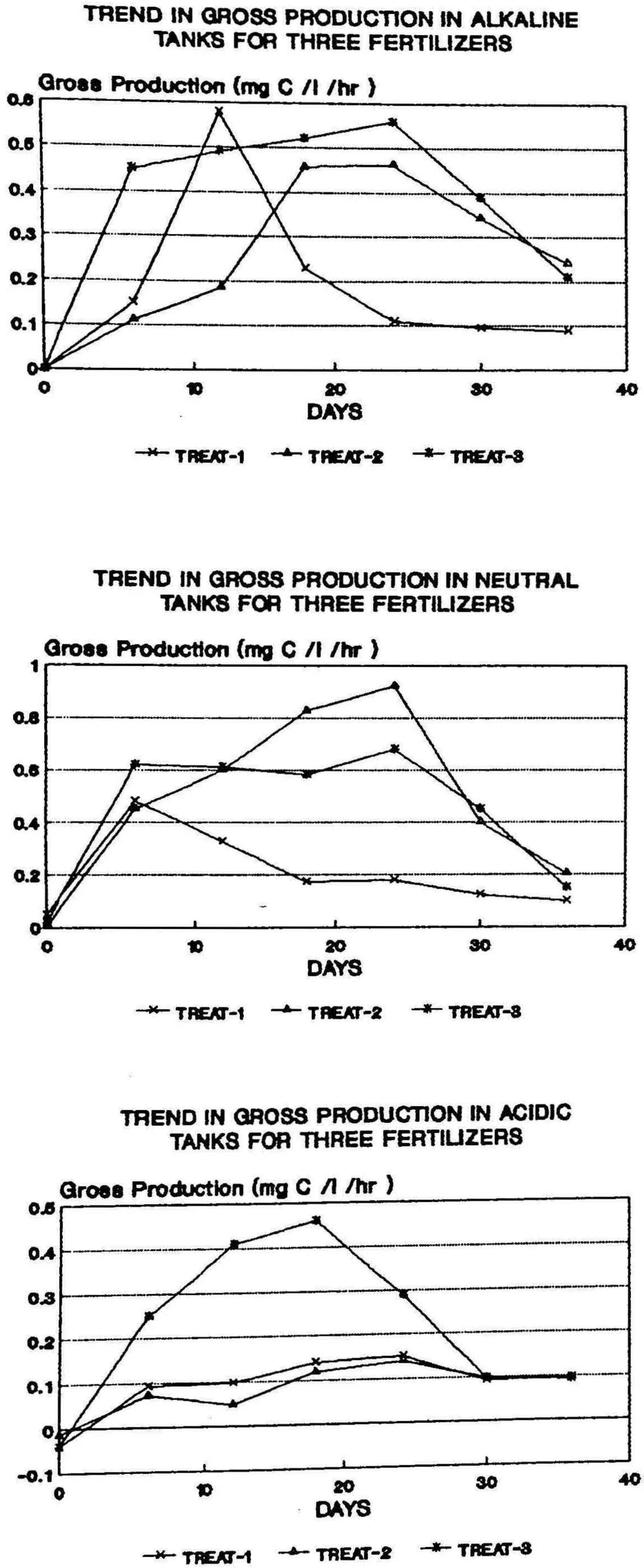

TREND IN GROSS PRODUCTION IN ALKALINE TANKS FOR THREE FERTILIZERS
Gross Production (mg C /l /hr)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
DAYS
TREAT-1
TREAT-2
TREAT-3
TREND IN GROSS PRODUCTION IN NEUTRAL TANKS FOR THREE FERTILIZERS
Gross Production (mg C /l /hr)
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
DAYS
TREAT-1
TREAT-2
TREAT-3
TREND IN GROSS PRODUCTION IN ACIDIC TANKS FOR THREE FERTILIZERS
Gross Production (mg C /l /hr)
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
10
20
30
40
DAYS
TREAT-1
TREAT-2
TREAT-3

FIG. 30

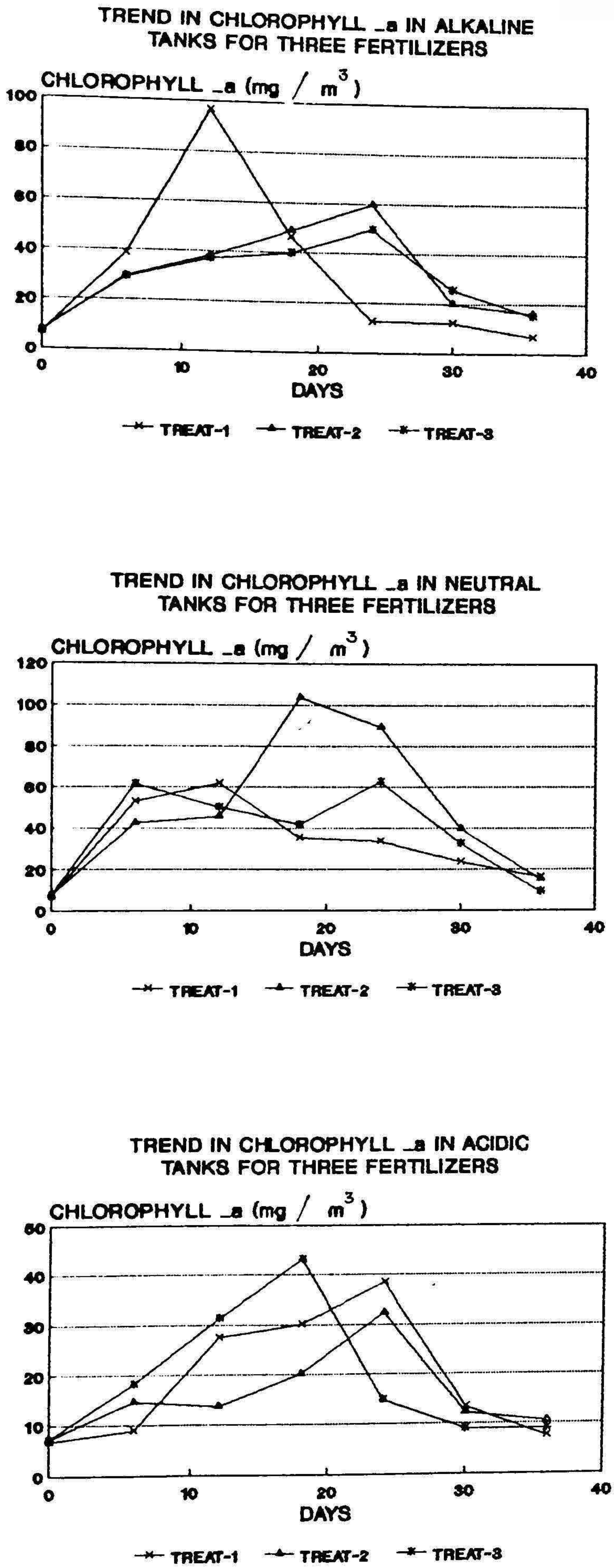

TREND IN CHLOROPHYLL _a IN ALKALINE
TANKS FOR THREE FERTILIZERS
CHLOROPHYLL _a (mg / m3)
100
80
60
40
20
0
0
10
20
30
40
DAYS
TREAT-1
TREAT-2
TREAT-3
TREND IN CHLOROPHYLL _a IN NEUTRAL
TANKS FOR THREE FERTILIZERS
CHLOROPHYLL _a (mg / m3)
120
100
80
60
40
20
0
0
10
20
30
40
DAYS
TREAT-1
TREAT-2
TREAT-3
TREND IN CHLOROPHYLL _a IN ACIDIC
TANKS FOR THREE FERTILIZERS
CHLOROPHYLL _a (mg / m3)
50
40
30
20
10
0
0
10
20
30
40
DAYS
TREAT-1
TREAT-2
TREAT-3

Fig. 31

	Soil-pH	Water-pH	Soil alk	Soil T.E.C.	Soil Org.C	Soil AV Phosphorus	Soil Nitrate	Water Phosphate	Water Nitrate	Water Cilicate	gross production	Cell Counts	Chl.a.	Total Pigments
Soil-pH	1.0000	0.9622 ..	0.7337 ..	0.8560 ..	-0.6665 ..	0.5272 ..	-0.1014	0.0405	0.1582	-0.5215	0.2266	-0.0519	0.2047	0.2815 .
Water-pH		1.0000	0.8133 ..	0.8127 ..	-0.6959 ..	0.4318 ..	-0.0726	0.0267	0.2057	-0.5667 ..	0.2403	-0.0542	0.2195	0.2835 ..
Soil alkalinity			1.0000	0.7185 ..	-0.5220 ..	0.1685	0.0015	-0.0697	0.3748 ..	0.5739 ..	0.4144 ..	0.1388	0.4648	0.4427 ..
Soil TEC				1.0000	-0.5327 ..	0.5467 ..	0.0577	-0.1311	0.2042	-0.5360 ..	0.2957 ..	-0.0089	0.3086	0.3350 ..
Soil Org.Carbo					1.0000	-0.3072 .	0.0435	-0.2026	-0.0999	0.3505 ..	-0.3044 .	0.1002	-0.3664 .	-0.4374 ..
Soil AV Phosphorus						1.0000	-0.1653	0.2219	-0.2783 .	-0.3405	0.1210	-0.2554 .	-0.0474	0.0433
Soil Nitrate							1.0000	-0.3806 ..	0.0671	0.0863	-0.2386	-0.0864	-0.2057	0.2041
Water Phosphate								1.0000	-0.2645 .	0.0165	0.2587 .	0.0143	0.1184	0.2492
Water nitrate									1.0000	-0.2612 .	0.1412	0.3745 .	0.3068 .	0.2000
Water silicate										1.0000	-0.4230	-0.0245	-0.3455 .	-0.3390 ..
Gross Production											1.0000	0.2631	0.8222 ..	0.7366 ..
Cell counts												1.0000	0.5087	0.5083 ..
Chl.a.													1.0000	0.9243 ..
Total Pigments														1.0000

TABLE 6 . Correlation matrix between selected parameters of soil and water quality in lab. expt.

.. Significant at 1% level (r > 0.322)

. Significant at 5% level (r > 0.250)

value. After an initial decrease, organic carbon increased gradually in both alkaline and neutral tanks whereas in acidic tank organic carbon increased throughout the experiment with slight deviation only in case of ammonium sulphate (treatment 2).

Correlation Matrix

From these experiments a definite pattern of correlation is observed between the soil and water phase (Table 6). Soil pH showed highly significant correlation with water pH (r=0.9622), soil-alkalinity (r=0.7337), soil TEC (r=0.856), available soil phosphorus (r=0.5272), all significant at 1% level. However, soil pH showed inverse correlation with soil organic carbon (r=-0.6665) and with water silicate (r=-0.5215). Similar trends were shown by water pH with all the above mentioned parameters. Both soil and water pH showed significant positive correlation with total pigments content.

Soil alkalinity showed highly significant correlation with gross production (r=0.4144), chlorophyll a (0.4648) and total pigments (r=0.4427) at $p < 0.01$. It was also positively correlated with water nitrate (r=0.3748), but with water silicate (r=-0.5739), an inverse correlation was found.

Soil TEC was inversely related to organic carbon (r=0.5327) and water silicate (r=0.5360); but it showed significant direct correlation with soil available phosphorus (r=0.5467) and with total pigments (r=0.3350), all at 1% level of significance.

Organic carbon content of soil showed significant inverse correlation with soil phosphorus at 5% level, with gross production and pigments also.

Soil phosphorus showed inverse correlation with the water nitrate, silicate and with the cell counts. Soil nitrate did not have any correlation with that of water. But it showed positive correlation with water nitrate. Water nitrate and phosphate are negatively correlated between each other. Water phosphate showed significant positive correlation with gross production (r=0.2587 at 5% level) whereas water nitrate showed good correlation with cell counts and chlorophyll a.

Water silicate had inverse correlation with gross production, chlorophyll a and total pigments, r being -0.423, -0.346, -0.339 respectively.

Gross production was significantly correlated at 1% level with chlorophyll a (r=0.8222) and total pigments (0.7366). However, with cell count there was a moderated correlation of gross production with r=0.2631. Cell counts showed positive correlation with chlorophyll a (r=0.5087) and total pigment content (r=0.5083) at 1% level of significance. Chlorophyll a was highly correlated with that of total pigments, r being 0.9243, significant at 1% level.

These correlation emphasizes the intimate interaction between soil and water at all stages as it was supported in earlier findings in culture ponds.

Taking into account all these findings it can be stated that:

In brackishwater ponds in the normal pH range nitrogen fertilizers are more important since in the present study, ammonium sulphate was showing a higher range of gross production in neutral pH range. This result is in full agreement with the findings of Smith (1984), Boyd and Daniel (1992), who emphasized the application of nitrogen fertilizers in brackishwater ponds in order to maintain N:P ratio which is otherwise low in these environment. Chattopadhyay and Chakraborty (1986) reported 10.4 mg/100 gm soil of available nitrogen in brackishwater fish ponds of West Bengal and suggested nitrogen fertilisation.

In alkaline condition, nitrogen fertilizers such as urea and ammonium sulphate failed to produce the desired effect on gross production as seen in the case of phosphate fertilizer application. Though urea gave an instant increase, it declined suddenly. The reaction causing disappearance of nitrogen from water has been studied to a lesser extent. However, it seems that in alkaline condition some of the nitrogen is converted to gaseous ammonia which escapes from the water into air. Another part is probably adsorbed by cation exchange reaction to soil colloids (Mandal, 1962) and then leached away.

Superphosphate application showed relatively higher gross production chlorophyll a and total pigments in very acidic & alkaline pH range though less than that of neutral tank. Earlier it was discussed that phosphorus is one of the elements easily subjected to retrogression in an acid medium as well as in alkaline medium. The retrogradation of phosphorus and accumulation of insoluble ferric or calcium phosphate in soils is very common (Banerjea and Mandal, 1965), thus a little amount of total phosphorus remains available in water. That may be the reason for a better gross production with this fertilizer in acidic and alkaline medium.

Though first-hand consideration should be given for correcting the acidity/alkalinity, it is also important that relatively higher doses of phosphate fertilizer along with nitrogen fertilizer may be better for acidic and alkaline soils of brackishwater ponds.

However, in ponds, since phosphate and nitrate are used up simultaneously in relatively constant proportion, a combination of these two fertilizers should be suggested.

As various authors reported richness of normal brackishwater ponds in available phosphorus, nitrogenous fertilizers should be applied in relatively more quantity along with other phosphoric and potassium fertilizer elements. It is also evident from the present observation that nitrogen fertilizers are more efficient than that of phosphate in normal pH range.

Again in the case of superphosphate, the acidity imparted by the fertilizer itself is favourable for algae growth. As a matter of fact, it has practically no effect within the normal pH range. But at low pH, superphosphate tends to reduce acidity, whereas at an alkaline pH of 7.5 to 8.5 the modification is in reverse direction (Brady, 1980).

Economic limit of fertilization as well as biological limit should be emphasized while suggesting relative doses of different fertilizers. In the experiments of Rashkes (1949) and Reich (1950), where even after adding large doses of phosphate fertilizer the recovery was seldom 0.5 ppm which was only a fraction of the phosphorus added. Similar result has been obtained when large amount of nitrogen were added to water. The concentration seldom exceeded 2 ppm.

Limiting factor, other than nutrients added by fertilization, may affect phytoplankton production itself. Such a case is described by Hepher (1958) where light becomes a limiting factor.

When each successive portion of a fertilizer added equals the value of the increase in fish yield received in return, the optimum dose of fertilizer is reached. Pahila (1989) reported that available phosphorus in soil is highest at pH 6.5 and slightly decreased at pH below and above 6.5. He suggested that phosphoric fertilizers upto 30 ppm was found to increase lab lab growth. Andarias (1989) reported that under brackishwater conditions the efficiency of phosphorus is lower than that of nitrogen fertilizers. He observed that liming decreased phosphorus efficiency. In the present study also liming in excess was found to decrease the efficiency of phosphorus.

MANAGERIAL MEASURES

The effect of acid soils on the fish pond condition is a major problem of fish culture in acid soils, the direct effect being deficiency of phosphorus. In acid saline water-logged soils of Kerala, sulphuric acid may be formed as a result of bacterial metabolism. Since this soil have high sulphur content, drying the pond bottom produces severe acidity. Under these condition the growth of algae and fish is very poor. Further losses of fish population can be caused by heavy rain, which brings a sudden influx of soluble aluminium from banks (Sunderson and Iyer, 1987).

Brinkman and Singh (1982) have developed a method of rapid reclamation of acid soils. In the early part of the dry season the ponds are dried thoroughly and harrowed. Then it is filled with brackishwater and pH of the water is measured immediately and at hourly intervals thereafter. When pH drops from 8 to 4 the pond is drained again and refilled. The process is repeated till the pH remains above 5.0. As many as three drying cycles with liming may rectify the situation.

They also suggested that N, P, K ratio 6-8-4 in the complete fertilizer is of optimum requirements. However, it is evident from the fertilization experiment conducted in lab, that nitrogen fertilizer application without proper reclamation of the soils are not useful. This is in full agreement with the report of Brinkman and Singh (1982). The authors also reported that in acidic soils losses by nitrification and denitrification from large dose of urea are considerable. So split application of urea or ammonium sulphate at short interval time would be efficient nitrogen management. As phosphate is fixed in acid saline soils by iron and aluminium, it should be supplied in small doses at frequent weekly interval. Slow release P-fertilizers may be a better source than superphosphate.

After proper reclamation of acidic ponds, the pond bottom should be dried and limed by broadcasting 0.5 tons/ha of lime stone together with 2 tons of chicken manure. Following flooding and stocking,nitrogen (urea) is added as top dressing at the rate of 8 kg N/ha every two to three weeks. In the present study also in which the effect of fertilization extended upto 2-3 weeks, this time limit to repeat fertilization is very much evident. However, phosphate is to be added every couple of days in small doses to avoid fixation - a weekly portion of about 5 kg P/ha is placed in jute bags just submerged to dissolve slowly (Sunderson and Iyer, 1987).

S U M M A R Y

The investigation on the *"Influence of different types of soil on the water quality in culture ponds"*. in four centres comprising eleven stations was carried out from April 1993 to November 1993.

The experiment conducted and the results of the above investigation are enumerated below.

1. Representative soil samples were collected from thirty seven different brackishwater ponds covering the main brackishwater fish farming areas of Kerala, air dried, ground and passed through relevant mesh sizes for further analysis.

2. Physico-chemical and biological properties such as grain size, pH conductivity, alkalinity, CEC, TEC, exchangeable Potassium, Sodium and Calcium, Organic Carbon, nitrate-nitrogen, Available phosphorus and sulphur of soil along with pH, salinity, dissolved oxygen, hardness, alkalinity, nutrients and pigments of water have been analysed during different seasons of the year.

3. Two way ANOVA and correlation matrix analyses were conducted to examine statistically the affinity of various hydrological and productivity parameters. Correlation between the selected parameters of soil and water, taking into account all types of soil and seasons were established.

4. Grainsize analyses revealed that, pond bottom soils are varying from sandy to clayey. Most of them belong to three categories viz. sandy loam, sandy clay loam and clay loam. It was found that available nutrients of soil increases with decreasing grainsize. Clay contents of soil showed significant correlation with exchangeable anions and cations and soil phosphate, nitrate and sulphur.

5. Water pH ranged from 6.07 to 8.78 whereas soil pH (wet) ranged from 5.09 to 8.40. Dry soil pH fluctuated between 3.53 and 7.28 in the present study. A significantly high correlation was obtained between the soil pH and water pH. On the basis of dry soil pH, around 84-89% of ponds studied, are found to have acidic soil and 11-16% of ponds are having neutral to weakly alkaline pH. Redox potential of soil varied from +228 to +549 mv, pH of both soil and water showed significant correlation with alkalinity, TEC and exchangeable cations with soil clay.

6. Overall salinity fluctuation in these culture ponds were found between 0.08‰ and 27‰ and a distinct pattern of decreasing trend in monsoon was noticed. Salinity has a positive significant correlation with soil EC and Exchangeable K^+, Na^+, Ca^{++}. It showed an inverse relation with water nitrate and water silicate. Soil conductivity (EC) ranged from 0.5 to 18 mmho/cm. Soil EC showed significant correlation with clay content, alkalinity, TEC, available sulphur and phosphorus of soil.

7. Water alkalinity ranged between 12 to 185 mg/l as $CaCO_3$ while that of soil ranged between 0.29 to 17.05 mg/gm. A highly significant correlation was found to exist between water and soil alkalinity. Out of the total ponds studied,

0 - 8% of ponds showed low productivity

14 - 51% low to medium

41 - 75% medium to high and

0 - 22% highly productive as far as water alkalinity is concerned.

8. Cation exchange capacity of soil varied from 6 to 28 me/100 gm whereas total exchangeable metallic cation ranged between 0.88 to 26.2 me/100 gm. TEC showed a significant positive correlation with cations like K^+, Na^+ and Ca^{++}. Seasonal fluctuation in TEC and CEC were inconsistant.

9. Exchangeable K^+, Na^+, and Ca^{++} of soil ranged from 55 to 2819 ppm; 113 to 4575 ppm and 320 to 6870 ppm respectively. These cations showed significant correlation with clay content and soil conductivity. Potassium was found to have significant correlation with pigment content that implies the influence of this on the productivity of water. Out of the thirty seven ponds studied,

5 - 11% were low

11 - 38% medium and

54 - 84% high in calcium content.

10. Soil organic carbon varied between 0.15% and 3.0% and had no significant seasonal variation and the thirty seven ponds studied were classifed as follows

3 - 16% of ponds low

48 - 64% average

22 - 30% optimum and

3 - 11% highly productive .

11. Available sulphur of soil ranged from 113 to 4375 ppm. It is significantly varying in different soil types and in different seasons. Apart from the clay content in soil other parameters such as soil EC and soil organic carbon were found to influence on available sulphur content of soil.

12. Water phosphate varied between 0.08 to 66 μg at/l, water nitrate from 0.31 to 74.3 μg at/l, water nitrite from 0.02 to 7.0 μg at/l and water silicate from 12.46 to 86 μg at/l.

Available phosphorus in soil fluctuated between 4.48 to 41.4 μg/gm whereas nitrate nitrogen of soil ranged between 4.08 to 16.05 μg/gm out of the total ponds studied,

17 - 48% of ponds were low

8 - 11% average

33 - 46% productive as far as soil available phosphorus is concerned.

From the significant correlation obtained in the present study, it can be inferred that nutrient status of water may be influenced by nutrients in soil.

13. The pigment contents, varied in different locations and showed appreciable increase during monsoon. Chlorophyll a was dominant followed by chlorophyll c. Significant correlation was found between these pigments with organic carbon, available phosphorus, exchangeable potassium of soil and also with nutrient of water phosphate, nitrate and silicate. This confirms that apart from light and dissolved oxygen, soil types and water quality are also found to influence the photosynthetic pigments and thus primary production, through present investigation.

Apart from the above field experiments/investigations, laboratory experiments on the same line were conducted and the results are given below.

14. The relative response of three fertilizers viz. urea, ammonium sulphate and superphosphate was judged in terms of productivity in three types of soils differing in their reaction - acidic (pH 4-5), neutral (7-7-5) and alkaline (8.5-10.5)

15. In the laboratory experiment also significant correlation were established between soil pH and water pH, soil alkalinity and water alkalinity, available phosphorus in soil and water reactive phosphorus, TEC and alkalinity, total pigment and alkalinity, which highlights the results

obtained as in the field conditions and confirmed the influence of soil types on water quality.

16. It can be inferred that acidic and alkaline conditions are not ideal for aquaculture, despite fertilizers application compared to neutrals which gives better production. So first hand attention should be given to rectify the acidity/alkalinity.

17. Nitrogenous fertilizers especially ammonium bases were found to be better in influencing the gross production under brackishwater conditions in neutral pH range.

18. In acidic and alkaline conditions, relatively higher phosphate fertilizers, of course along with nitrogenous fertilizers gives better production as it is clear from the present study.

19. On the basis of the overview of this investigation, it is concluded that culture ponds in different types of soils are independent with regard to physico-chemical parameters and the contributing factors which varies from one to other types of soil.

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